Thermoregulation

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Definitions

- homeothermic = where body temp is actively maintained within tight limits (mammals)
- poikilothermic = body temp fluctuates with changes in ambient temp (reptiles)
- interthreshold range (ITR) =
  - range of core temps that does not trigger autonomic thermoregulatory responses (0.2-0.5 degC)
  - within ITR we are effectively poikilothermic
- thermoneutral zone (TNZ) = range of ambient temps where VO2 is a minimum (autoreg by vasoC or vasoD alone):
  - prem = 34-36
  - term = 32-34
  - adults = 22-28
  - another definition = environmental temp range which body temp is normal and remains normal while heat production & evaporative heat loss both remain at minimum (usually referring to naked body)
- within TNZ heat production = heat loss.
  - achieved by using minimal VO2
    - by vasoC / vasoD
    - not by shiver/sweating/exercise
- neutral temp = ambient temp where VO2 = minimum:
  - prem = 34
  - term = 32
  - adult = 28
- critical temp = ambient temp where naked, non anaesthetised, cannot maintain normal core temp:
  - prem = 28
  - term = 23
  - adult = 1

heat = a form of energy. Can be transferred from hotter to colder substance ie down a gradient
  - analogous to a solute
  - measured in calories: 1 calorie (standard international unit) = amount of energy required to ↑temp of 1g of pure water by 1deg celcius
- temperature = measure of thermal state of a substance/body/environment which will determine whether heat will transfer to or from substance/body/environment
  - analogous to a concentration

solute & concentrations:
  - if you add more solute (ie heat) to a solution then measured concentration (ie temperature) will increase.
  - the concentration (temp) will determine whether solute particles (heat) will move to an area of lower conc (temp) or vice versa
  - if you halve a substance with a temp x: will get 2 halves with same temp (conc) but with half the heat (quantity)

specific heat capacity:
  - = amount of heat required to raise the temp of a 1kg substance by 1 kelvin (J/kg/K)
  - specific = quantity expressed in terms of units mass
  - examples of SHC:
    - man = 3.5 kJ/kg/C
    - water = 4.18
    - blood = 3.6
    - gasses = very low ∴ small heat transfer can cause significant temp change in gas
- air = 1.01

- heat capacity = amount of heat required to raise temp of given object by 1K (J/K)
  \[ \text{heat capacity} \times \text{mass} \]

- mean body temp = \( \frac{2}{3} \) core temp + \( \frac{1}{3} \) average skin temp

- body heat content = heat capacity \times \text{mean body temp}

- latent heat:
  - latent heat of vaporisation = heat needed to change liquid to vapour without a change in temperature
    \[ \text{latent heat of vaporisation of water} = 0.58\text{kcal/g} \]
  - latent heat of fusion = heat needed to change solid to liquid without a change in temp
  - latent heat of crystallisation = solid dissolving on or out from a liquid

- specific latent heat
  - heat needed to convert 1kg of a substance from one phase to another at a given temp (J/kg)
  - lower starting temp = ↑ed energy needed

- critical temp = temperature, above which a substance cannot be liquefied, no matter how much pressure is applied

**Intro**

- norm core body temp maintained within 0.5-0.8 (usually 36.5-37.3) with slight variations:
  - diurnal -
    - circadian fluctuation = 0.5-0.8
    - lowest asleep, rises with activity
  - gender:
    - female show menstrual monthly variation - ovulation \( \Rightarrow \) ↑ up to 1deg
  - individual

- tight range of norm temp aka set point range:
  - if temp moves outside this range \( \Rightarrow \) physiological effector mechanism activated to counteract change

**Anaesthesia Summary**

- anaesthesia = challenge to thermoregulatory mechanisms:
  - removal of behavioural responses
  - loss of tonic peripheral vasoc \( \Rightarrow \) redistribution of heat to peripheries (away from core)
  - ↓ threshold of effector responses
    \[ \text{↓ size of ITR - to } \sim 5\text{degs} \]
  - ↓BMR by 20-40%
Physiology
Compartment Model

• body heat distributed unevenly
• 2 main compartments
  • central (core):
    - major trunk organs
    - brain = 2/3 body's heat
    - temp narrow range 36.5 - 37.3
  • peripheral compartment:
    - limbs, skin, sub cut tissue = 1/3 body heat content
    - wide temp swings from close to zero - 40deg
      • norm room conditions = av temp 30-32
      • gradient of ~6deg maintained by tonic vasoC in vessels supplying periphery
    - anaesthesia:
      • heat moves peripherally = ↓core temp by ~1deg
      • = dilutional heat loss effect rather than NET heat loss

Heat Production vs Loss

Heat production
• metabolism:
  • basal metabolism ~40kcal/m2/hr (~2000kcal/day)
  • = indep of thermoreg mechanisms ie ↑ed in:
    - kids
    - ↑growth hormone
    - thyroxine
    - febrile illness
• amount of heat generated by metabolism depends on substrate:
  - glucose & aa’s ~ 4kcal/kg
  - fat ~ 9.3kcal/kg
• products of metab:
  - 2/3 energy ⇒ dissipated as heat
  - 1/3 ⇒ ATP generation

By Adam Hollingworth
• shivering:
  - ↑ heat production by x6
  - autonomically mediated
  - infants <3/12 cannot shiver
• exercise - ↑ x20 heat production
• non-shivering thermogenesis:
  - ↑ x3 heat production esp imp in neonates
• vasoC -
  - autonomically mediated
  - ↑ s temp gradient between core & periphery
• behaviour:
  - putting on more clothing
  - quantitatively the most imp factor!!!!

**Heat Loss**

• radiation (40%):
  - infrared electromagnetic wave transfer of heat from warm object to a distant cooler surface
  - further ↑ ed by vasodilation
  - depends on 4th power of temp difference:
    - ↑ OT temp by 2 deg ⇒ ↓ heat loss by $2^4 = 16$ fold
• convection:
  - = motion of liquid or gas which carries energy from warm area to cool area
  - when layer of air next to skin moves/disturbed ⇒ removing insulating properties
  - heat exchange = proportional to
    - temp difference between skin & surrounding air = as much as 15 deg
    - square root of air velocity
• evaporation: (25% - skin 15%, lung 10%)
  - each kg of water (sweat) ⇒ dissipation of 0.58 kcal/g of heat from body with evaporation
    - \( \text{latent heat of vaporisation of water} \)
  - <10% heat loss but can ↑ ↑ with open surgery (evap skin prep & open wound)
  - more imp in neonates/prems due to:
    - ↑ skin permeability
    - ↑ BSA
  - = only way to lose heat if environment is warmer than core temp
• conduction (5%) -
  - = 2 material objects in direct contact. Temp of one is higher than the other \( \therefore \) they equalise
• behaviour = undress, seek cooler environment
• overall:
  - vasoC = main physiological way of preventing heat loss ie ↓ radiation & ↓ evap
  - respiration = contribute ~10% heat loss
    - 8% evap of water
    - 2% heating of air
Physiological Control of Body Temp

- similar to other homeostatic control systems
- thermoreg control system =
  - afferent
  - central CNS integration
  - efferent effector limb

Afferent Limb

- temp sens organs:
  - naked nerve endings found all over body in:
    - skin -
      - located in sub-epithelium
      - predominant location (20% all afferent thermal info)
    - s/c tissues
  - respond to changes in temp by changing rate of firing → CNS

- 2 types of temp sens neurons:
  - cold receptors:
    - bulbs of Krauss (santa Krauss)
    - outnumber warm receptors 10:1
    - respond to changes in temp range 10-36deg
    - most afferent cold input from skin/periph compartment
    - input to A delta fibres
  - warm receptors:
    - bulbs of Ruffinian (Roof on fire)
    - response range 30-45deg
    - input to unmyelinated C fibres

- thermally sensitive neurons can undergo adaptation:
  - occurs between 20-40deg
  - sensation of heat/cold will gradually fade to thermal neutrality
  - temp >40 → tissue damage → warm sensation → pain sensation

- ascending thermal traffic via lateral spino-thalmic tract in ant cord
  - some signals modified at spinal level:
    - spinal injured pt regulate temp better than expected

Central integration

- hypothalamic = main integrator
- ant hypothalamus:
• integrates inputs in pre-optic area
  \(\rightarrow\) contains temp sensitive cells
• general rule =
  • cold input from periphery
  • warm input from core
• posterior hypothalamus:
  • compares aggregated input with pre-determined set point temp range 36.5-37.3
  • instigates effector responses
• BUT human thermoregulation also occurs at multi other levels eg NRM in pons, PAG in spinal cord

**Efferent Limb**
• posterior HT \(\rightarrow\) autonomic effector response to cold ie vasoC & shivering
• ant HT \(\rightarrow\) responses to warm ie sweating & vasoD

**Characteristics of Thermoregulatory Effectors**
• 3 main chars:
  • threshold
  • gain
  • max response intensity
• each mechanism contains all 3 chars
• General Anaesthetic effects:
  • ↓ thresholds
  • no effect on gain + max response intensity
  • removes ability to mount behavioural response:
    • in extreme cold: vasoC & shivering have limited efficacy and vice versa in extreme heat
• range of ambient temps tolerated is ↓ed if effector mechs are inhibited:
  • neurological disease \(\rightarrow\) ↓ shivering
  • drugs eg atropine \(\rightarrow\) ↓ sweating
  \(\Rightarrow\) \(\therefore\) ↓ed min tolerable temp, ↑ed max tolerable temp

**Threshold**
• core temp at which response triggered
• thresholds can be altered by:
  • diurnal rhythm
  • gender
  • exercise
  • food
  • infection
  • disease
  • drugs/anaesthesia
• vasoC threshold = 36.5
• shivering = 36-36.2
• GA’s effect on ↓ threshold \(\rightarrow\) an ↑ interthreshold range (norm 0.2-0.5) to ~5degs

**Gain**
• =rate of change of effector response with given change in temp
  \(\Leftarrow\) ie = slope of response curve
• \(\therefore\) gain of shivering = rate of ↑ shivering as core temp continues to ↓ below shivering threshold
• vasoC = very high gain ie max vasoC reached after small ↓ in temp below threshold
• shivering = less gain ie takes larger in temp to reach max response

**Max Response intensity**
• =upper limit (plateau) of effector response
Effector Responses

- Non shivering Thermogenesis (NST)
- Sweating
- VasoConstriction
- Vasodilation
- Shivering

Non shivering Thermogenesis (NST) (see paeds)
- includes (non restricted to) metabolism of brown fat
- brown fat = specialised fat:
  - multinucleated cells
  - many mitochondria
  - abundant blood supply
  - abundant autonomic nerve supply
  - catecholamines mediate metabolism
  - substrate used mostly = FA’s
- cold stimuli ⇒ NA release ⇒ uncoupling of oxidative phosphorylation ⇒ ↑heat production /gram of fat (rather than ATP production)
- no mechanical work done
- brown fat found in
  - abdomen esp perinephritic
  - around large blood vessels
  - interscapular area
  - base of neck
- brown fat = 2-6% neonate total body weight
- ↑brown fat metab redirects CO to brown fat (by ↑~25%) ⇒ direct heating of blood as well
- NST needs O2 ↓. cold & hypoxia = v bad
- x3 heat production in neonate (in adult has v little effect)

Sweating
- mediated by symp ns postganglionic cholinergic nerves
- prevented by:
  - nerve blockers
  - anticholinergics eg atropine
vital as = only mechanism which can dissipate heat if environ temp > core temp
latent heat of vaporisation = 0.58kcal/kg water (= 2.42 MJ @ body temp)
sweating rate can > 1litre/hr for short periods
  ↓ = heat loss up to x15 BMR
<37/40 prem baby unable to sweat

VasoConstriction
=1st autonomic response to cold
skin blood flow autoreg consists of components:
  • thermoregulatory
  • nutritional
skin flow regulated via A-V shunts in distal vasculature (finger/toes/palms/earlobes:
  • well innervated anastomotic connections between arterioles + venules
  • anatomically + functionally distinct from nutritional capillary network
    ↓ . A-V constriction does not compromise nutritional needs of periphery)
innervated by α-adrenergic SNS
  ↓ minimally affected by circulating catecholamines
  • up to 10% of CO can flow through these shunts
    ↓ doesn't usually effect haemodynamic changes as larger arterioles control MAP are un-
  ↓ blood flow vary from 1ml/100g skin/min ⇒ 150ml/100g/min via A-V anastomotic system

Vasodilation
mediated via A-V shunts
max cutaneous vasoD at temp above that which causes max sweating intensity
  ↓ ie max sweating reached before max vasoD
extreme heat stress:
  • blood flow through skin 7 l/min ie whole resting CO
vasoD ineffective if ambient temp > core temp

Shivering
= involuntary oscillatory pattern of skeletal muscle activity that occurs once cold core threshold (for
  shivering) is reached ( ~35.9)
vigorous shivering ⇒ ↑metabolic heat production:
  • briefly = x6
  • sustained shiver = x2
components of shiver:
  • rapid frequency component = 200Hz
  • slow frequency = 4-8Hz synchronous waxing & waning mm contraction which centrally
    mediated
shiver motor centre =
  • located between ant & post HT
  • inhibited by impulses from heat sensitive area (ant HT)
efferent pathway has multiple connections:
  • RF in mesencephalon
  • pons
  • medulla
    ↓ ends on spinal α motor neurons
  • see ↑ed mm tone prior to shivering
infant <3/12 cannot shiver
Peri-Operative Shivering
common & distressing for pt ie can ↑pain
• causes are complex but hypothermia is most impt
• not assoc with hypoxaemia (hypoxia inhibits it)
• prevention of hypothermia is best Rx
• other options =
  • pethidine 0.33mg/kg IV
  • tramadol 25mg
  • fentanyl 1mcg/kg
  • clonidine 2mcg/kg
  • ondansetron 0.1mg/kg

**Paediatrics**
• thermoregulatory responses well developed in term neonates BUT hypothermia develops rapidly if compensatory mechanisms overwhelmed
• neonates have min insulating s/c fat
• neonates have large BA : volume ratio ie x2.5 adults
• open/flaccid posture neonates ⇒ ↑heat loss
• large head (with ↑ed relative cerebral flow) ⇒ ↑heat loss
• large min ventilation ⇒ ↑heat loss
• infants <3/12 dont shiver
• term baby can sweat >37.2 BUT prems <37 week unable to sweat
• principle heat production mechanism = NST
• poorly developed behavioural responses ie max = crying
Anaesthesia & Thermoregulation

General Anaesthesia

• effects:
  • behavioural responses totally abolished
  • significant ↓ autonomic regulation -
    - specifically thresholds ⇒ ITR x10-20
      • warm response threshold ↑ ed,
      • cold response threshold ↓ ed
        ↓ all anaesthetic agents ↓ cold threshold in dose dependant fashion
  • GA usually ⇒ mild, inadvertant hypothermia in 3 phase pattern:
    • phase 1 (1st 30-45min) =
      - rapid ↓ core temp 1-1.5 deg
      - due to
        • redistribution & dilution of core heat ⇒ periphery
        • vasoC cold threshold ↓ ed
    • phase 2 (2-3hrs):
      - gradual linear ↓ core temp of ~1deg over 2-3hrs
      - due to heat loss > heat production
      - BMR during GA ↓ by x20-40%
      - loss of heat via radiation, convective, evaporative
    • phase 3
      - = plateau where heat loss = metabolic heat production
      - seen when pt sufficiently hypothermic to reach vasoC cold threshold

Regional Anaesthesia

• mechanisms:
  • redistribution of heat = main mechanism
  • ↓ ed afferent temp input to CNS - due to block
    - pt may deny feeling cold but be hypothermic & shivering
  • ↓ ed thresholds (as GA) -
    - partially due to co-sedative drugs given
  • shivering -
    - less effective as less mm mass to shiver ie only upper limbs/body
- gain & max intensity ↓ed by ~50%
- overall effect is less than GA as vasoD restricted to lower body/limbs
  ↓ see ~0.5 degree drop in temp
- pattern of response similar to GA phase 1 & 2
- phase 3 =
  - not seen as vasoC not possible via blocked nerves
  - may see passive plateau in well insulated pts during minor surg
  ↓ serious hypothermia possible in major surgery
- combined regional/GA = exceptional high risk of hypothermia:
  - ↓ effector response - ↓ shivering & ↓ vasoC
  - ↓ afferent inputs

**Consequences of PeriOperative Hypothermia**

- drop of 1-2 deg below norm:

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<table>
<thead>
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<tbody>
<tr>
<td>Cardiac morbidity</td>
<td>increased × 3</td>
</tr>
<tr>
<td>Periop wound infections</td>
<td>increased × 3</td>
</tr>
<tr>
<td>Periop blood loss</td>
<td>increased by 30%</td>
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</tbody>
</table>

- cardiac M+M due to:
  - ↑ circulating catecholamines ⇒
    - ↑ MAP (↑ afterload)
    - ↑ cardiac irritability = ↑ arrhythmias

- periop wound infections:
  - directly related to s/c wound tissue O2 tension
  ↓ compromised by hypothermia induced vasoC
  - mild hypothermia directly impairs immune function:
    - ↓ B cell mediated antibody production
    - ↓ non specific oxidative bacterial killing by neutrophils

- periop blood loss:
  - impaired platelet function - via ↓ thromboxane release
  - ↓ clotting factor enzymes function
  ↓ NB lab coag tests = norm as performed at 37 deg in lab

**PeriOperative Hypothermia & Drug Metabolism**

- drug enzyme systems = temp sensitive
- muscle relaxants half lifes:
  - vecuronium =
    - <35 = ↑100%
  - atracurium =
    - <33 = ↑160% duration
- (less temp dependant)

• volatiles:
  - hypothermia ⇒ ↑ tissue solubility
  - MAC halothane & isoflurane: ~5% ↓ with each 1deg ↓ core temp
  - (at brain temp 20deg no anaesthesia required)

• IV drugs - ↓ 1deg =
  - ↑ plasma conc:
    - propofol by 10%
    - fentanyl by 5%

**Prevention PeriOp Hypothermia**

• 3 strategies:
  - minimise heat redistribution
  - cutaneous warming during anaesthesia
  - internal warming

**Minimise Heat Redistribution**

• preop warming of periph compartment - eg forced convective warm air (Bair hugger)
  - need ~1hr prewarming to be effective
  - difficult to logistically achieve

• preop pharm vasoD:
  - facilitates core ⇒ peripheral redistribution of heat
  - does not effect core temp as pts other (ie not vasoC) thermoreg responses are intact
  - eg nifedipine ⇒ ↓ s extent of initial redistribution hypotermia by 50%

**Cutaneous Warming During Anaesthesia**

- passive insulation:
  - eg space blanket
  - ↓ s cutaneous heat loss by ~30% by trapping layer of still air
  - additional layers of passive insulation do little else

- active warming:
  - much more effective
  - initially: core heat ⇒ periph compartment
  - only way to correct is to ↑ heat in periph compt > core .: reversing gradient

- Most effective = forced air convective warming (Bair):
  - warm air replaces cold air
  - convection ⇒ ↑ ed heat gain as forced air is warmer than skin
  - must be directly next to skin with no intervening layers
  - larger area covered = more effective
  - blankets on top of Bair hugger ⇒ ↓ efficacy by preventing air circulating
  - NB: if ↓ ed lower limb bloody supply (aortic clamp) then should avoid LL warming in order to ↓ effects distal ischaemia

**Internal Warming**

• warmed IVF:
  - 1 litre fluid at room temp ⇒ ↓ core temp ~0.25deg
  - .: always use warm fluids or fluid warmers esp if major haemorrhage
  - needs to be used in combo with other techniques - not successful alone

• airway humidification:
  - limited use
• <10% metabolic heat lost via this route
• cardiopulmon bypass: transfers heat at rate & magnitude more greatly than any other route
• peritoneal dialysis/lavage = very effective but not usually applicable
• amino acid infusions:
  • can give during anaesthesia ⇒ ↑ metabolic rate
  • ml for ml compared to crystalloid will lead to ↓ ed hypothermia
  • not really used in practise due to concerns about cardiac outcome with ↑ ed metabolic rate
Electrical Measurement

**Non Electrical**
- aka direct reading
- categories:
  - liquid filled
  - dial
  - chemical

**Liquid**
- generic advs:
  - simple
  - linear expansion with temp
- generic disadvs:
  - slow
  - breakable/injury
  - non-remote
  - intermittent
  - non recording

**Mercury Thermometer**
- adv: reliable, cheap, familiarity, can be made in maximum reading form
- disadvantage:
  - slow - 2-3mins
  - risk of injury high
  - cannot read colder than -39C

**Alcohol Thermometer**
- adv:
  - cheaper than mercury
  - better at v low temps
- disadv:
  - unsuitable for high temp readings (alcohol boils at 78.5deg)
  - scale is less linear

**Dial Thermometers**
- bimetallic strip:
  - 2 dissimilar metals fixed together in coil which expands/contracts by different amounts based on temp changes
  - causes coil to tighten/relax ⇒ change on indicator scale
  - used commonly in TEC-vaporizers
- Bourdon gauge:
  - gauge attached to a sensing element containing small tube of mercury or volatile liquid
  - works on 3rd Gas law: temp change ⇒ for fixed volume, absolute pressure of gas varies with absolute temp
  - this then recorded on calibrated scale

**Chemical**
- single use:
  - strip containing rolls of cells which contain dye & melt at certain temp
  - higher temp ⇒ more cells melt ⇒ more dye released
- reusable:
  - cells have diff long chain polymers whose optical properties change with temp
chloresteric liquid crystals which change colour with temp

Electrical Techniques

- aka remote reading thermometer

Resistance Thermometers

- based on fact that electrical resistance of metal ↑s linearly with ↑temp
- configuration:
  - platinum wire resistor
  - battery
  - ammeter to measure current (calibrated for temp display)
- but:
  - system is too simple
  - would be too sensitive
  - needs a Wheatstone bridge
∴ not really used

Thermistors

= what is used in theatres everyday
- small bead of metal oxide (eg cobalt)
- resistance falls exponentially as temp rises (opposite to platinum resistor)
- adv:
  - can be made very small eg end of flexible probes
  - cheap to make
  - accurate
  - greater change in resistance with smaller temp changes (compared to resistance thermometers) ie ↑ sensitivity
  - quick response time -
    - cos is small ∴ has small heat capacity
    - essential for use in CO measurement via thermal dilution technique
- disadv:
  - calibration may change if exposed to severe temp changes eg heat sterilised
  - hysteresis
  - ageing

Infrared Thermometers

- body gives off thermal electromagnetic radiation over range of wavelengths
- objects at body emit primarily infrared radiation
- intensity of radiation & wavelength depend on temp
- lens focuses infrared thermal radiation onto a detector
- detector is a concentrated area of many thermocouples. Called a thermopile
- detector converts radiant power to an electrical signal which can then be displayed in temp units
- needs to account for ambient temperatures
- used for tympanic & skin probes

ThermoCouples

- at a junction of 2 dissimilar metals ⇒ small voltage produced
- magnitude of voltage depends on temp at this junction
  ≡ Seebeck effect
- junction = thermocouple
- use metals eg copper & constantin
- 2nd junction is needed as
  - reference junction AND
• complete circuit  
• reference junction needs to be kept at constant temp while other junction = temp probe  
• adv:  
  • measuring probe can be made in form of a needle  
  • small heat capacity ∴ rapid response  
  • calibration does not change even if couple needs to be replaced  
  • accurate to 0.1°C

**Clinical Aspects of Temp Measurement**

• core temp can be measured directly or indirectly at various sites:
  • pulmon artery (via PAC)  
    - = gold standard  
    - not practical unless PAC indicated  
  • tympanic membrane:  
    - accurate as is close to ICA  
    - probe can damage TM  
    - more suitable for single measurements  
    - indirect infrared TM monitors are safer & used more frequently (lie approx 1cm from TM)  
  • axillary - reflects core temp if placed close to axillary artery with arm adducted  
  • nasopharynx:  
    - reasonable reliable - close to ICA  
    - easy to access  
    - disadv:  
      • bleeding - esp old or anticoag  
      • inaccurate if exposed to airflow eg too deep & lying next to ETT/LMA  
  • lower oesophageal:  
    - ideally needs to be lower 1/3 to avoid false readings from gas flow in trachea  
    - oesophageal stethoscope with integrated thermistor = sit behind LA, very accurate  
  • rectal/bladder:  
    - close to core temp but is a lag as organs are not well perfused  
    - affected by faeces/rate of urine flow  
    - bladder > rectal at reflecting core temp  
  • skin:  
    - useful in neonates - sensor on ant abdo wall  
    - useful in detecting core:periph gradient  
    - affected by  
      • perfusion  
      • hydration status  
      • sweating  

• indirect measurement of CO = simultaneous recording of periph & core temp:  
  • ↓CO ⇒ compensatory ↑vasoC ⇒ ↑SVR ⇒ ↓periph temp ⇒ ↑core:periph gradient  
  ⇐ : ↑core:periph gradient = ↓CO
## Examples of Temps at Various Sites

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<th>Site</th>
<th>Temp c/f core</th>
<th>Problems</th>
</tr>
</thead>
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<tr>
<td>Buccal</td>
<td>0.2 – 0.4 below</td>
<td>bleeding</td>
</tr>
<tr>
<td>Nasopharyngeal</td>
<td>~ core</td>
<td>perforation, wax / obstruction</td>
</tr>
<tr>
<td>Tympanic</td>
<td>~ core</td>
<td></td>
</tr>
<tr>
<td>Axilla</td>
<td>0.4-0.7 below</td>
<td></td>
</tr>
<tr>
<td>Rectum</td>
<td>~ or &gt; core</td>
<td>perforation, cultural, slow</td>
</tr>
<tr>
<td>Lower oesophagus</td>
<td>0.5 below</td>
<td>cooling by trachea if too high</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>~ core</td>
<td></td>
</tr>
<tr>
<td>Bladder</td>
<td>~ core</td>
<td></td>
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<tr>
<td>Skin</td>
<td>&lt; core</td>
<td>dependent on skin perfusion</td>
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