Indhold

Del I

Background

1 | Anatomy and Physiology

Top coming..

1.1 Macrovascular system

The main function of the cardiovascular system is the blood supply of the whole body and the transportation of metabolites. The propulsion of this is the heart. It generates through the sputum strength of the left ventricle the systolic blood pressure. The pressure difference between the heart and the periphery emerging there from, ensures the blood flow. The blood flows from regions with high pressure, like the aorta, to regions with low pressure, like the periphery.

The heart supplies the body through two circuits with blood. On this occasion the heart regulates the blood allocation with adjustment of stroke volume and heart frequency.

The oxygen-rich blood accumulates in the left ventricle. From there the blood is thrown out through the aortic valve into the aorta and via the arteries spread into the whole body. The venous system returns the meanwhile low in oxygen blood back to the heart into the right atrium. From there the blood flows into the right ventricle and is thrown out through the pulmonary valve into the lung arteries. In the lung happens the gas exchange of the blood. Subsequent the oxygen-rich blood flows via the pulmonary veins back to the left heart to supply the body.

As mentioned, there are two types of vessels, arteries and veins. The difference between those two types of vessels is on the one hand that arteries transport the blood away from the heart and veins solely transport blood to the heart. On the other hand, there are some differences in the structure of arteries and veins. Arteries consist of three different layers, tunica interna, tunica media and tunica externa. The tunica interna consists of vascular endothelium, the tunica media consists of smooth muscle cells and elastic fibres, the tunica externa consists of connective tissue and also elastic fibres.

Furthermore, there are two different types of arterial vessels. In arteries of the elastic type prevail the elastic fibres in the tunica media. This allows an abrupt extension of the vessel during the systole and ensuing constriction, due to this the blood is transported. This phenomena is called windkessel function. In arteries of the muscular type prevail the muscular fibres in the tunica media. This allows regulation of the lumen by constriction and dilatation, whereby the resistance and the blood flow in the organs is regulated.

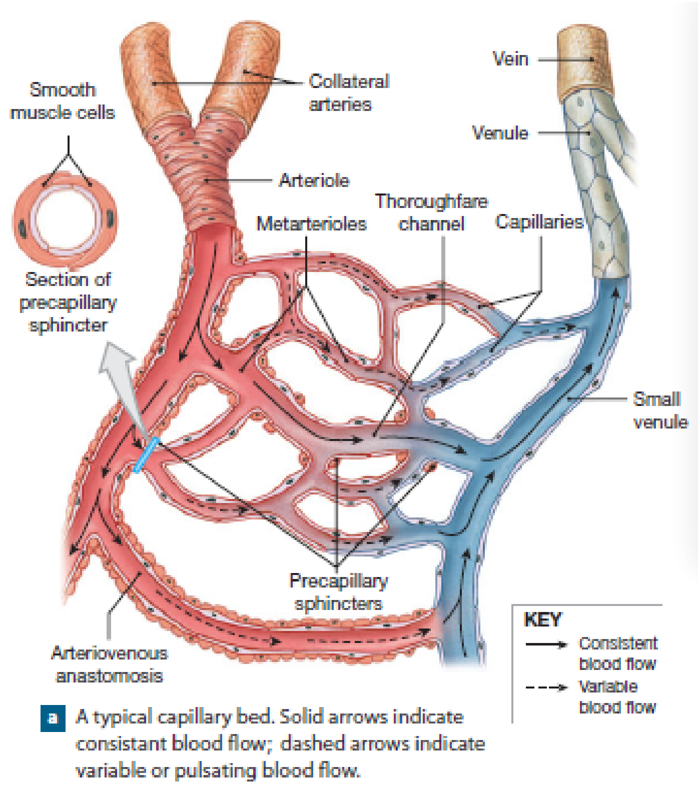
Venous vessels are similarly structured like arterial vessels, however they are thinner and have also semilunar valves inside, to inhibit back flow inside the vessels. This system is supported by muscle pump.

The arterial and the venous vessel system are connected through the capillary system. [martini2012]

1.2 Microcirculatory system

In this section the hand will be used as an example point, to describe the microcirculatory system.

The heart and larger arteries and veins are what we usually associate with the cardiovascular system, but actually those are only mainly used for transport of blood. Instead it is the capillaries, that permeate most tissues, that is responsible for the perfusion of tissue. These are the only vessels that permit exchange between the vessel and the surrounding interstitial fluids. Capillaries are made not of single individual fluid conductors like veins and arteries, but instead formed capillary beds. Here they work as a interconnected network of vessels. As mentioned before the arterioles divide into dozen of capillaries which then merge into a venule, after the blood has been de-oxygenated. A capillary is divided into two segments, first the metarteriole and second the capillary. The blood flow between arterioles and venules can also be a direct connection, made by an arteriovenous anastomosis. This works as a bypass diverting blood flow around the capillary bed. An example of the structure of the capillary bed can be seen on figur 1.1.[**martini2012**]



Figur 1.1: The basic structure of a capillary bed, with arteriole on the left side of the bed and a venule on the right.

Each capillary entrance is controlled by a precapillary sphincter, which is composed of smooth muscle cells, that are able to contract or relax and thereby limit access of blood flow to certain capillaries. The blood flows relatively slow within the capillaries giving time for the two way exchange of nutrients and wastes. [**martini2012**]

1.2.1 Vasmotion

The flow within the capillaries varies. This is due to the earlier mentioned precapillary sphincters contracts and relaxes. The opening and closing of sphincters is part of the autoregulation process performed at a local level, to control the blood flow. Local changes in concentration of chemicals and interstitial fluids eg. dissolved oxygen concentrations in tissue cause the sphincters to dilate permitting a greater flow of blood to the area. The cardiovascular system does not contain blood enough for every vessel a capillary beds to be filled with blood. Therefore only 25 perfect of the vessels in a capillary bed contains blood, and vessels activity needs to be well coordinated.[**martini2012**]

Under normal circumstances cardiac output remains stable and the control of local blood flow happens through local peripheral resistance within local tissues. The regulation of cardiovascular activity is controlled by local homeostatic mechanism. These make sure that demands such as oxygen and nutrients are meet and wastes are disposed. [**martini2012**]

Factors that promote dilation is called vasodilators and can be some of the following:

- Decreased oxygen level or increased CO2 level
- Lactic acid or other acids generated from tissue cells
- Nitric oxide NO released from endothelial cells
- Rising concentrations of potassium ions or hydrogen ions in the interstitial fluid.
- Chemicals released during local inflammation
- Elevated local temperature

A vasodialation will result in increased oxygen, nitrients, buffers released to recreate homeostasis. Factors that stimulate contriction is called vasoconstricters and can happen due to following:

- Damaged tissue
- Aggregating platelets

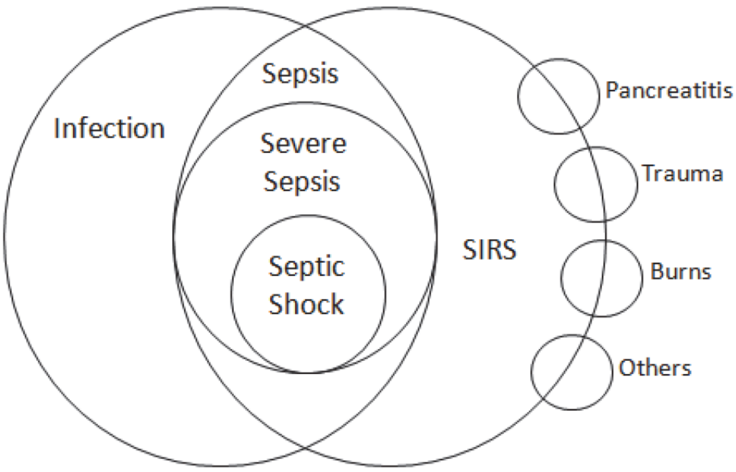
Factors that affect tissue perfusion is cardiac output, peripheral resistance and blood pressure[**martini2012**].

2 | Pathalogy

Top coming..

2.1 Stages in sepsis

Sepsis is a condition, that develops on behalf of Systemic inflammatory response syndrome (SIRS) with pressence of an infection or bacteria in the tissue, within the body which triggers an immune response. This response often overexposures the workload on the immune system to fight the inflammation or bacteria. The infection or bacteria can be anywhere in the body's tissue. Some of the normal macrohaemodynamics of sepsis are abnormal body temperature, abnormal heart rate, oxygen extraction and abnormal blood pressure [**plunta2010**, **kanta2014**]. Sepsis is increasing condition in the population. Different studies suggest estimates of the incidence of sepsis, but the identification of diagnosis of sepsis can vary, why the numbers may also vary from place to place. The North American Centers for Disease Control found an increase in sepsis incidence pr. 100 000 patients, from 73.6 in 1979 to 175.9 in 1989, which is an increase of 82% in 10 years [**baudouin2008**, **kanta2014**]. The Dr Foster Organisation found an increase by 53% from 1996 to 2002 in the hospitals in the United Kingdom. Causes for the increase in incidence can be due to the increasing elderly population, with cronic conditions undergoing invasive procedures [**baudouin2008**]. Sepsis is often assosiated with three stages, sepsis, severe sepsis and septic shock. This is illustrated in figure 2.1.



Figur 2.1: Relation between SIRS and infectoin. Showing the stages in sepsis and some of the causes of SIRS which include pancreatitis, trauma, burns etc.

2.1.1 Sepsis

Under the condition of sepsis several things happen, mainly to the micro circulatory system at the capillary level, that leads to impaired homeostasis in the body. Infection or other bacteria that's responsible for causing some irregularity is present in the blood and in the tissues around the the vessels. Among the first thing's that happens when the body encounters an infection, white blood cells are recruited to release molecules that will fight the infection. Molecules that interact with the endothelial in the blood vessels, like nitric oxide (NO), are released. The interaction causes the vessels to dilate to increase the blood vessel diameter and permeability. The increased diameter slows down the blood flow, which causes a drop in blood pressure. Also the vessels permeability is increased. This reaction happens multiple places in the body where there is infected tissue present and will cause systemically vessel dilation. The characterization of sepsis is SIRS as a result of infection. [**baudouin2008**, **kanta2014**]

2.1.2 Severe sepsis

When the permeability of the vessels is increased there will be more fluid in the tissue and the cells will get less oxygen because the oxygen has a harder time to get to the demanding tissue. Also the endothelial of the vessels will get damaged when the white blood cells try to destroy the pathogens. This triggers coagulation and clotting is formed in the damaged areas in the blood vessels. These clots can break off into the blood and cause further harm. At a point the damaged vessels leads to more leakage, because there will be a point where the coagulation can't follow up. Organs will start to dysfunction at this stage. The characterization of severe sepsis is presence of sepsis with organ dysfunction and hypoperfusion is often included in this state. The mortality rate for patients with severe sepsis are about 25 to 30% [**baudouin2008**, **kanta2014**].

2.1.3 Septic shock

Septic shock happens when the body has undergone sepsis for a greater duration of time. This stage is characterized by a condition with hypotension even after adequate fluid resuscitation is given. Because of lactic acidosis the cells are not getting a sufficient supply of oxygen and therefore the cells will begin to die. This can lead to a very dangerous state, where organs begin to fail because they get to damaged to function. When multiple organs get damaged the state in septic shock reaches multiple organ failure also called multiple organ dysfunction syndrome (MODS)[**baudouin2008**, **kanta2014**]. The mortality for patients with septic shock are in the region of 40 to 70% [**kanta2014**].

3 | Infrared Thermal Imaging

The following chapter will include an introduction to infrared imaging, where some general concepts and physical principals will be explained. Furthermore it will be elaborated how a device measures infrared radiation.

3.1 Infrared Thermography

Infrared tomography is an imaging technique that utilizes infrared radiation emitted from nearly any objects. The existence of infrared radiation was first discovered in 1800 by Sir Frederick William Herschel. His experiments lead to the knowledge that there were a light spectrum beyond the visual spectrum humans are able to perceive.[**ignacio2017**, **optris2009**]

Infrared thermography is commonly used to calculate surface temperatures and important concepts in the understanding of this are heat and temperature. Temperature is a measure for the internal energy within an object and can be defined at the average kinetic energy of the object. Heat is the energy that passes from a warm object to another colder object. A warm object will decrease in internal energy and a cold object will increase due to the temperature difference and therefore the heat transfer. In the human body, a constant temperature is keep, due to several factors and therefore the temperature will not decrease even though a heat transfer to the surrounding environment occurs. The environmental temperature do have an impact on how large the heat transfer gradient is. If a body is in a cold environment, the emitted heat will be grater than the absorbed. In the same way, if the environment is much warmer than 37 degrees Celsius, a greater absorption than emission will occur and the body will increase in temperature.[**ignacio2017**]

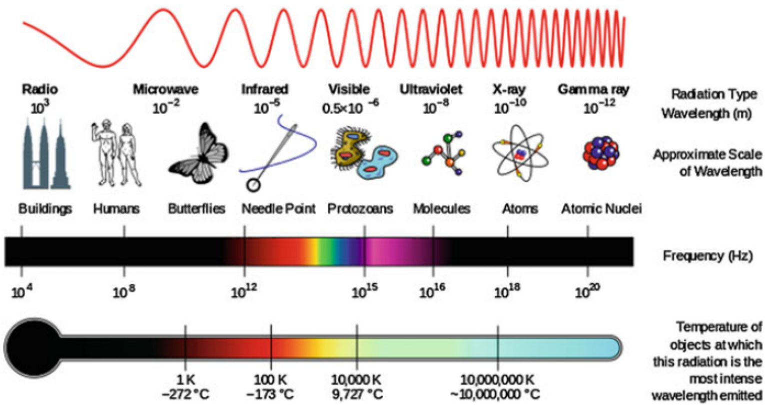
3.1.1 Physical principals

Any object above absolute zero emits energy-electromagnetic radiation depending on its temperature. Absolute zero is 0 Kelvin or -273.16 Celsius. To put that into perspective the human body has a temperature around 37 degrees Celsius.[**ignacio2017**, **optris2009**]

Electromagnetic radiation is a propagation of energy trough a medium without the transportation of mass. An electromagnetic wave is made of the relationship between frequency (f), wavelength (λ) and the speed of light (c). This is stated in the equation of wave motion.[**ignacio2017**]

$$\lambda = \frac{c}{f} \tag{3.1}$$

Depending on the frequency and wavelength certain characteristics arise from what is called the electromagnetic spectrum. The electromagnetic spectrum is the electromagnetic energy that is emitted. This extends from radiation of low energy such as radio waves and infrared, to waves of higher energy in form of eg. X-rays. A graphical representation of the electromagnetic spectrum can be seen on figur 3.3.[**ignacio2017**]



Figur 3.1: The electromagnetic spectrum with wavelength, emitters, frequency and temperature.[**ignacio2017**]

Infrared radiation is also known as thermal radiation because the relationship between temperature and infrared radiation. Temperature of the human body permits radiation in the infrared spectrum, but objects of much higher temperature are capable of emitting radiation in the visible and UV spectrum. This has to do with the difference between object and environmental temperature. If the temperature of these are relatively close to each other, the radiation emitted will be within infrared wavelengths. Infrared radiation have a wavelength from 769nm to 1mm. Objects emit more radiation in some region regions compared to others. Because of this is the infrared spectrum classified in the three regions, near, middle and far infrared. Near is between 769nm and 2.5μm, middle 2.5μm to 50μm and far 50μm to 1mm. The human body emits most radiation in the far infrared part, and most thermal cameras are build with this in mind. Near and middle cameras are used to measure gases.[**ignacio2017**]

3.1.2 Measuring thermal energy

The theory of the black body is important to understand the absorbtion and emission of light relative to temperature, because the theory of the black body are used to describe the laws of infrared radiation and its relationship to temperature. The black body is an ideal perfect emitter of infrared radiation because it absorbs all electromagnetic radiation permitted to it, and it emits the same amount of radiation as it absorbs, the absorption and emission sums up to be zero. Spectral emissive power, also denotted E_λ is the energy emitted by a surface in relation to time and range of wavelength. Figure 3.2 shows an graphical illustration of spectral emissive power of the black body for specific wavelengths when the temperature changes. Radiation at different frequencies according to temperature are also shown in the figure.

The knowleadge of this principe helps in the understanding of how infrared radiation behaves, and how temperature affects the frequenzy of the signal.

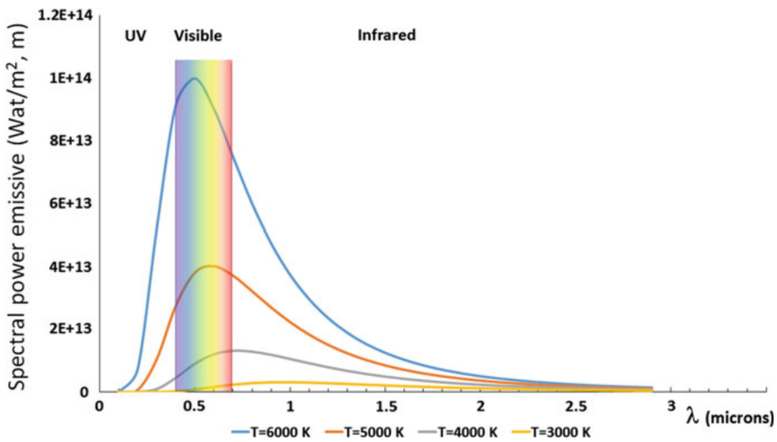
The radiation from the human body which has a temperature at 37 degrees celcius emits the maximum energy of 9.3μm, which means that most of the radiation is in the far infrared spectrum. Room temperature emits radiation higher in the infrared because the temperature is lower than the human body.

- Maybe describe wien's displacement law... (wavelength of the peak of the blackbody radiation curve decreases as the body temperature increases)

Stefan boltzmann's law? (radiation energy from black body is proportional ti the fourth power of its absolute temperature)

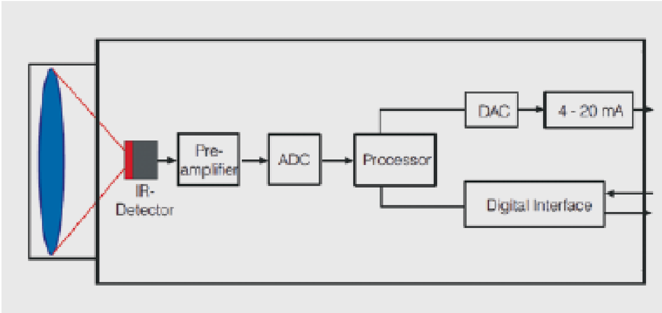
Planck's law...

- RIO (region of interest) The lens are important to capture the image you want (dunno if this is relevant to mention?)



Figur 3.2: Spectral power emissive

Measuring thermal radiation uses the knowledge that electromagnetic radiation is proportional to the internal energy. With a lens, the radiation that is emitted is focused onto a detector element in the camera that generates an electric output proportional to the radiation. The electric output is undergoing amplification and further signal processing.This allows the final output signal to be viewed as a temperature for the object. [**optris2009**] The black body is used for calibrating thermometers...



Figur 3.3: Simplified block diagram of an standard infrared camera.[**optris2009**]

A bit more needs to be written here i think..

Extra notes that i'we just copied that we can use later

The advantages of non-contact temperature measurement are obvious – it supports:

- Temperature measurements of moving or overheated objects and of objects in hazardous surroundings
- Very fast response and exposure times
- Non-interactive measurement, no influence on the measuring object
- Non-destructive measurement
- Measurement point durability, no mechanical wear

4 | Hemodynamics

Hemodynamics explains the movement or flow of the blood. It is influenced by parameters like blood pressure, blood volume, cardiac output, blood composition and viscosity, elasticity of the vessels and lumen of the vessels. It is possible to measure some of the hemodynamic parameters non-invasive, and also to calculate parameters.

4.1 Physiological Base

The regulation of the blood pressure happens with baroreceptors in the wands og the big arteries in chest and neck area. These receptors register the changes of the elongation of the vessels and transmit this information to medulla oblongata. With the received pressure informations initiates the medulla oblongata, if necessary, regulatory measures. For the short-term regulation is the sympathicus responsible. Both, middle-term and long-term regulation, is made by the kidneys. For middle-term regulation messenger substance are released, which entail vasoconstriction. The long-term regulation occurs per pressure diuresis or reabsorption in the kidneys.

It is possible to measure different blood pressures at different places in the cardiovascular system, for example the mean arterial pressure. The MAP increases with ejection of the stroke volume and decreases with outflow if the blood in the periphery. The central venous pressure states the pressure in the venous system and complies approximately the pressure in the right ventricle. CVP depends on the filling volume of the venous system.

Effects on the blood pressure have cardiac output, total periphery resistance and the viscosity of the blood.

The cardiac output CO states the blood volume, which is pumped by the heart per time unit. The calculation of the CO as follows.

$$CO = HF \times strokevolume \tag{4.1}$$

The total periphery resistance is the flow resistance of the systemic circulation and results from the sum of all vessel resistances. TPR depends on MAP , CVP and CO.

$$TPR = \frac{MAP - CVP}{CO} \tag{4.2}$$

4.2 Physical Base

To consider the hemodynamics, it is possible to draw conclusions by analogy of physical laws. Especially of Ohm's law $R = \frac{U}{I}$ or rather $I = \frac{U}{R}$.

A special case of Ohm's law constitutes Hagen-Poiseuille's law in the field of fluid dynamic and rheology. Hagen-Poiseuille's law describes the laminar flow of an homogeneous Newtonian fluid through a rigid pipe depending on characteristics of the fluid and of the pipe.

Blood is an inhomogeneous suspension of liquid and corpuscular components, whose viscosity η depends on more factors than the temperature, and is consequently no Newtonian fluid. Nevertheless it is possible to draw conclusions by analogy out of Hagen-Poiseuille's law for the computation of the hemodynamics.

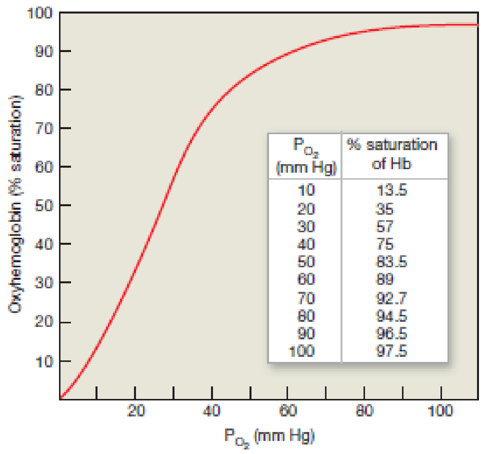
$$\frac{V}{t} = \frac{r^4 \times \pi \times \Delta P}{8 \times \eta \times I} \tag{4.3}$$

Here is the volume flow equivalent to the electrical current I and the pressure difference ΔP to the electric Voltage U. Thus, the calculation of the Resistance as follows.

$$R = \frac{8 \times I \times \eta}{r^4} \tag{4.4}$$

The logical conclusion is, that the volume flow increases 16 times and the resistance decreases 16 times for double radius r.

In the blood is the oxygen tied to a large extent by hemoglobin. The oxygen saturation describes the percentage of the oxygenated hemoglobin. With rising oxygen partial pressure increases the oxygen saturation. This relation between sO_2 and pO_2 is showed by the oxygen binding curve.



Figur 4.1: The oxygen binding curve shows the relation between sO_2 and pO_2

The oxygen content of the blood depends on both, the oxygen saturation and the oxygen partial pressure. cO_2 is calculated by the sum of the hemoglobin bounded and the physical dissolved oxygen.

$$cO_2 = Hb \times 1,34\frac{ml}{g} + pO_2 \times 0,003\frac{ml \times dl}{mmHg} \tag{4.5}$$

The available oxygen is calculates by the oxygen content of the blood and the cardiac output.

$$DO_2 = cO_2 \times CO \tag{4.6}$$

The consumption of oxygen is calculated by the difference between the available oxygen in the arterial and the venous blood and the cardiac output.

$$VO_2 = (c_aO_2 - c_vO_2) \times CO \tag{4.7}$$

Therefore one can draw a conclusion from the available and the consumption of oxygen to the cardiac output.