Laser-Doppler in Phlebology

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Microcirculation can be studied via:

- Capillaroscopy – for morphologic changes
- Thermography – for regulation of microcirculation
- Oxygen and carbon dioxide measurement – for exchanges of gases
- Laser-Doppler measurement – for flow in microvessels

Fundamentals of laser-Doppler

Hitting a moving blood cell creates a frequency shift of the back-scattered light, which is detected by the photo detector.

- Laser-Doppler measures the total local blood perfusion in the tissue. This includes capillaries, arterioles, venules and shunts.
- It is not possible to measure only the capillary (nutritive) blood perfusion.
- Non-invasive or invasive (muscular measurements) can be performed.
- Usually this is a non-invasive measurement.
- We are interested in the perfusion of the tissue which depends on the amount of moving blood cells and the **velocity** of these cells. Perfusion measurement result = Concentration of moving blood cells × Velocity of these cells.
- Subject of examination is always about **the same very small volume**, for this reason this instrument is informative mainly for the velocity of cells.

How to compare measurements

- Standardization of instrument and measuring methods are required to compare results between laser-Doppler users.
- Probes and equipment parameters must be equal.

- The LDPM (Laser-Doppler Pressure Measurement) should be calibrated using the Perimed motility standard - a colloidal suspension of latex particles.
- Perfusion units (PU) are arbitrary and cannot be presented
- Exact depth cannot be determined
- Measuring depth is influenced by tissue properties

Parameters that influence microcirculatory measurements are:

- Temperature of the subject considerable effect
- Systemic blood pressure considerable effect
  (recommended to be monitored continuously
  on animals and measured on humans)
- Status (stress, food, medicine, smoking, etc) considerable effect
- Mental activity considerable effect
- Physical activity considerable effect
- Age considerable effect
- Gender minor or no difference
- Race minor or no difference

A wide fibre separation will measure deeper

- PU and flow is not the same but there is a linear relationship between the two.

  (Nilsson GE,1984, Ahn H, et al , 1987.)

Microcirculation has (or is influenced by):

- Extreme dynamics (temporal variations)
  - Blood perfusion can differ several thousand percent between a cold and warm fingertip.
  - Large Spatial Variations
  - Blood perfusion can vary up to 100 percent in forearm skin if the probe is moved 1 mm.

Special cases:

Plastic surgery
- Monitoring of superficial and buried flaps (LDPM) Plastic Surgery – Flap Monitoring Example

PeriSoft for Windows gives early warning of poor circulation

Oral cavity
- Pulpal or gingival measurements (LDPM)

Alimentary tract
- Mucosa in oesophagus, stomach, small intestine (LDPM)

-Measurement of flux in mucosa of colon and rectum.

Inner organs
- Intestine, kidney, liver, pancreas (LDPM, LDPI)

Muscle
- Invasive measurements (LDPM)

Endothelial Dysfunction

Characterized by:

- Impaired endothelium-dependent vasodilatation
- Decreased production/local bioavailability of nitric oxide (NO)

Caused by:

- General cardiovascular risk factors such as smoking, hypertension, hypercholesterolemia etc.
    - Treatment of risk factors helps restore endothelial function
- Suggestive role of oxidative stress
    - Reduced symptoms in patients on a diet with high content of antioxidants

TESTS

Provocations are used to enable reliable and repeatable measurements despite the temporal and spatial variations in the microcirculation.

- Heat provocation (Tissue capacity, maximum dilatation)
- Occlusion (Post Occlusive Reactive Hyperemia)
- Drugs (Patch test, Injections, Iontophoresis)
- Posture (Veno-Arterial Reflex, Leg Elevation)
- Cooling (Raynaud disease or syndrome)
- Electrical stimulation (C-fibre stimulation)

Local heating

- Biphasic response
- Two independent mechanisms cause increase in skin blood flow during local heating
  - Fast responding mediated by axon reflexes /afferent cutaneous sensory nerves, unknown neurotransmitter (first phase)
  - Slow responding mediated by local NO production (second phase)

Heat Provocation for studying ischaemia

Healer - Heat increases circulation, which means normal response

Non-healer - Heat doesn't increase circulation, which means exhausted response possibilities

Heat provocation to determine tissue reserve capacity - healing capability (LDPM) and amputation level

Post Occlusive Reactive Hyperemia (PORH)

During occlusion a lack of oxygen develops which dilates vascular beds and increases perfusion. This is hyperemia.

- Reflects the endothelium-dependent regulation of the microcirculation

- Prostaglandins (prostacyclin) are the major vasodilating mediators in PORH
- Hypercholesterolemic patients show disturbed PORH that can be improved by diet or statin treatment

Laser-Doppler as an aimed diagnostic tool:

Iontophoresis

- Iontophoresis is used to transport drugs through tissue barrier
    - Combined with laser-Doppler and used as a valuable diagnostic tool – to study the influence of drugs in the vascular bed:
        - Acetylcholine
        - Sodium Nitroprusside
        - Pilocarpine
        - Bretylium Tosylate

Allergy patch testing

- Allergy patch test

  Substances of different concentrations to be tested are applied on the skin

Burn Depth Assessment

- Healing process
    - Reduced perfusion in burnt areas, increased perfusion in surrounding skin.
- Assessment of burn depth
    - Partial thickness burns have a high perfusion because the microvasculature is still intact

Wound healing
– Measurements on skin

- Laser Doppler will show
    - Ischemia
    - Tissue perfusion reserve capacity
      (% change from normal to maximum dilatation after heat)
    - Inflammation (high baseline)

Fundamentals of microcirculation

Number of vessels

Aorta	1	
Vena Cava	1	
Arteries	125	
Veins	300	
Arterioles	5.000.000	($5x10^6$)
Venules	10.000.000	($1x10^7$)
Capillaries	4.000.000.000	($4x10^9$)

Vasomotion

- Vasomotion – regulation of the local perfusion
  - Controlled locally as well as systemically
  - Usually 4-10 cycles per minute (cpm)
  - Varies with the temperature
  - Can be divided into:
    - High – 4-10 cpm (myogenic)
    - Medium – 1-4 cpm (neurogenic)
    - Low – 0.1-1 cpm (endothelial)
  - Strongly reduced in microneuropathy and problematic flaps

Toe pressure measurement with laser-Doppler

- Digital systolic blood pressure
  - Limb ischemia and diabetic patients
  - Pressure cuff + laser-Doppler probe distal to the cuff

  - High accuracy and off-line analysis

- Pressure cuff and laser Doppler probe are connected to the PeriFlux 5000
- The cuff is inflated well above systolic blood pressure, then deflated linearly

Multi-channel pressure

- Simultaneous measurements can be used for fast evaluations
  - Arm pressure + 2 x Toe pressure*
  - Arm pressure + 2 x Ankle pressure*
- Toe-brachial index
- Ankle-brachial index

  - Patients with impaired endothelial dysfunction show a different blood perfusion pattern upon local heating.

Summary of fundamentals

- Perfusion = Concentration of moving blood cells × Velocity of these cells.
- Important to minimize the effect of all external parameters when measuring (environment, temperature, stress, movement, etc.).
- Microcirculation have extreme dynamics and great spatial variations .
- Provocations are used to enable reliable and repeatable measurements despite the temporal and spatial variations in the microcirculation.
  - Heat, Occlusion, Drugs, Posture, Cooling, Electrical stimulation, etc.

Laser-Doppler in Phlebology

Study on telangiectatic veins

Aim of the telangiectatic vein study

- Is there any difference between the circulation of the spider veins and the surrounding skin ?
- Which has a greater influence on their circulation, perforator vein insufficiency or AV shunts?
- In all cases or only in some of them ?

Arterial pulse can be detected with CW Doppler in the region of some spider veins.
If the pulse sounds over a spider vein, it is a suspicious sign.

Laser-Doppler flow measurement on spider veins:

Results

In some telangiectasia there is a very high flow, in some others there is not a big difference, or the flow is slower in the telangiectasia than in the surrounding skin.

Scanning Laser-Doppler Imager clearly shows that there is a higher speed circulation in the telangiectasia.

On average **circulation in telangiectasia** is 1.8 times higher than in the surrounding skin.

What does this result mean?

- Higher flow is more frequent than congestion,
- Higher flow in some spider veins suggests open AV shunts.

This and some other experience suggests the presence of AV shunts behind certain spider veins.

Conclusion of this measurement

- Higher flow in some spider veins suggests open AV shunt
- Histologically found shunts can be open
- Not every telangiectasia is connected to an open AV shunt
- Higher flow is more frequent than congestion

What AV-shunts develop in the skin?

It is supposed that these are the normal skin AV shunts, which are diseased because of:

- trauma
- estrogen hormone
- hereditary disposition
- high venous blood pressure etc.

Iatrogenic complication because of AV shunts:

- Necrosis of the skin as a consequence of too much sclerosing agent given into a telangiectasia.
- Polidocanol went into the supply artery through an AV shunt.
- Paravenously given polidocanol never causes any complications.

New Theory of Spider Vein Circulation

- Previously it was thought that telangiectasias are fed by high pressure perforator veins.
- According to our observations, it seems that AV shunts also participate in telangiectasia circulation and perforator veins drain this blood.

Study on corona phlebectatica paraplantaris

Corona phlebectatica paraplantaris is a symptom of chronic venous insufficiency.
It resembles telangiectasia.
The question is, what kind of circulation is it?

Patients

- 20 persons were examined
- Wide age range: 25 – 86 years old
- Different stages of chronic venous insufficiency (C2 – C5)
- Some with additional diseases
- Influence of different medicines cannot be ruled out

In spite of this great variety, the findings were almost the same in every case. This is why our results are interesting.

Method

Laser-Doppler detectors are placed over the vessels and the normal skin nearby as well.

Course of examination:

1. Record the resting flow
2. Heat the detectors to 44 ºC for 2 mins
3. Strangulate leg with a 220 mmHg cuff for 3 mins and afterwards deflate cuff (PORH)
4. Bring patient from a lying position to a sitting one (VAR)

What did we expect?

- Stasis in venules of CPP
  - lower flux than in the surrounding skin
  - lower pulse amplitude than in the surrounding skin
- Similar responses to the provocation tests as in the surrounding skin

Results

Resting flow: High flux and expressed pulsation in CPP.

- The question is: why is the flux high?
  - there are many small or some big vessels - which contain very much blood
  - the flow is fast in the vessel
- The laser-Doppler signal is proportional to the number and velocity of moving blood cells in illuminated superficial skin microvessels.

Pulsation and cross-section:

Cross-section of CPP in general is 4.5 times bigger than that of a capillary. The curve is therefore 4.5 times magnified. In spite of this, the amplitude of pulses is much higher in the CPP than in the capillaries of the surrounding skin.

Basic flow value results:

- In 18 out of 20 limbs the flow is higher in the CPP than in the surrounding skin
- Maximum 7 x – minimum 0.5 x higher
- In 12 cases 1 – 2 x higher
- The mean is 2.3 x higher flow

Tests

Heating response:

- Similar response
- Amplitude of pulse increases
- In CPP there is also an increase during cooling period
- In a few cases there was an increased response in the normal skin region

Evaluation of heating:

- There is no significant difference in the increase of flow in the two regions
- There is no significant difference in the area beneath the curve

220 mmHg compression test:

- Compression stops circulation in the capillaries, but in CPPs it increases the flow (in 14 cases out of 20)
- Compression can cause not only the flow to increase but also the amplitude

Post-occlusive reactive hyperaemia (PORH) test

- There is not a significant difference in the PORH response of the two regions

Veno-arterial reflex test: Similar curves in both regions.

Observations of the study

- Basic flow is higher in CPP than in the capillaries of the surrounding skin.
- Amplitude of pulse is higher in CPP venules than in the capillaries of control skin.
- In some provocation tests, curves of CPP and the control area are different not only in their size, but also in their shape.

Clinical Observations

- Blanching – sclerosing agent makes a spasm in the supplying artery through an AV shunt
- Too much sclerosing agent was given, and some small arteries were occluded, which caused necrosis of the skin.

Conclusions

- There is a high flux and very expressed pulsation in the venules of CPP that suggest the role of AV shunts in their circulation.
- During strangulation of the limb the flow also increases, which could be a consequence of a retrograde flow from the compressed veins to the ankle.

Hypothesis

- Our hypothesis is that some AV shunts of the many in the ankle region are out of regulation because of the damaging effect of severely and chronically impaired venous circulation.
- The venules of CPP drain the blood of these non-regulated shunts.

Possibilities in laser-Doppler studies in the field of phlebology

- Our opinion is that laser-Doppler examination is suitable for research work where microcirculation and phlebology meet.
- Currently it seems telangiectasias and CVI are the main diseases where it can be used in everyday phlebology practice.

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