Theory of Operation

Laser Doppler Tissue Perfusion Technology

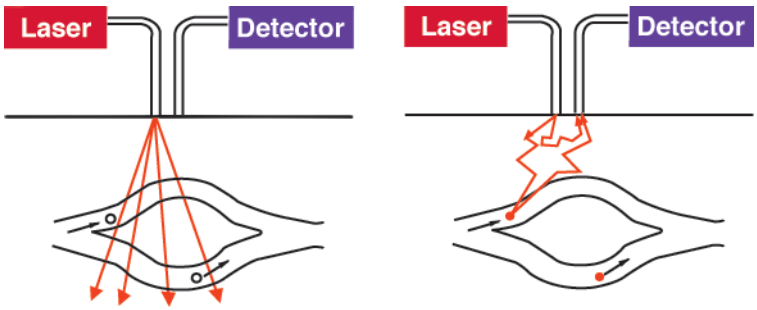
LASER DOPPLER THEORY

A low intensity beam of monochromatic light, emitted from a laser diode inside a BLF Monitor, travels via the Probe's fiber optic light guide through the Probe head to illuminate the tissue under study. There the laser beam is scattered by reflective components within the tissue. A portion of the light is reflected back, via the Probe's receiving fiber optic light guide, onto a photo detector inside the Monitor. Generally, this received light has been reflected many times by stationary structures within the tissue as well as by one or more moving particles (mainly red blood cells) within the tissue. Through the Doppler effect these moving particles change some of the received light signal's frequency.

The received signal spectrum is processed in the Monitor in accordance with algorithms derived by Dr. R.F. Bonner[1] for this type of reflective environment to calculate flow, velocity and mass of the flowing red blood cells within the tissue area sampled by the Laser Doppler Probe (velocity and mass are only available as output signals on BLF22). While the actual volume of tissue sampled by the BLF varies with the optical properties of the tissue, it is approximately one cubic mm.

TISSUE PERFUSION FLOW, VELOCITY & MASS

Dr. Bonner's theory presents a framework to calculate tissue perfusion parameters in absolute units: tissue perfusion flow in units of milliliters per minute per hundred grams of tissue (ml x min^{-1} x 100 g^{-1} of tissue), mass of the flowing red blood cells (in grams per 100 g of tissue) and their average flow velocity in m/sec. In practice this is somewhat problematic. The most significant reason is that the actual volume of tissue sampled is unknown. The tissue volume in the calculations is assumed to be 1 mm^3, but it may vary widely with differing optical properties of the tissue. The flow output is proportional to absolute flow in the tissue sampled, but since the quantity of tissue sampled maybe different from one spot to another and one patient or subject to another, the "constant" of proportionality differs for each placement of a Probe. Units, therefore, are reported as TPUs (tissue perfusion units) which are proportional to the absolute units (ml x min^{-1} x 100 g^{-1} of tissue).



Laser Doppler emits light at a given frequency and then detects the frequency of the reflected light. Light that is reflected by moving particles, such as blood cells, experiences a frequency or Doppler shift which is proportional to the motion of the particle. That shift is used to determine the flow, velocity and mass of the blood.

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Laser Doppler Uses and Limitations

Besides being unknown, the volume of tissue sampled is very small; this is both a strength and a weakness. Since the volume sampled is so small, Laser Doppler Perfusion Monitors can look at very localized perfusion without being influenced by underlying tissues. However, its readings can be misunderstood as, for example, a gauge of a whole organ perfusion rather than very local perfusion. This can be exaggerated by the unit ml x min^{-1} x $100g^{-1}$ of tissue. Assuming the nominal 1 mm^3 is sampled, this sample weighs about 0.001 g; therefore, the more correct but unprecedented unit to quote would be hundredths of microliters per minute per milligram of tissue (0.01µL x min^{-1} x mg^{-1} of tissue.) Of course, these units have the same ratio of volume to weight but it is important to remember that only about 1/100,000 of that one hundred grams of tissue is being sampled.

While typical flow ranges for certain tissues (notably free flap donor sites used in microvascular reconstructions) are very desirable and potentially useful, they must be used with great care. These ranges are subject to very large tolerances because Monitor to Monitor, Probe to Probe, tissue site to tissue site, and patient to patient variations are all additive.

From this discussion, we can conclude that the best and most significant usage for laser Doppler-based Tissue Perfusion Monitors is for relative measurements. If the Probe can be placed at one location, to continually monitor a given site for the duration of the critical period, the changes noted are directly proportional to tissue perfusion changes (flow, mass, flow velocity) in the sampled tissue when proper monitoring technique is maintained.

[1]Bonner, RF, Clem, TR, Bowen, PD, Bowman, RL, "Laser-Doppler Continuous Real-Time Monitor of Pulsatile and Mean Blood Flow in Tissue Microcirculation, Scattering Techniques Applied to Supra-Molecular and Nonequilibrium Systems" 1981. Chen, SH, Chu, B, Nossal, R, eds. New York: Plenum, pp 685-702.

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Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells "gold standard" transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.

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