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Comparison of Laser Doppler Perfusion Imaging, Laser Doppler Flowmetry, and Thermographic Imaging for Assessment of Blood Flow in Human Skin

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In this study we compared three non-invasive methods of measuring skin perfusion, thermographic imaging (TI), laser Doppler flowmetry (LDF) and the new technique of laser Doppler imaging (LDI). Seven normal volunteers were studied in a temperature-controlled room with an ambient temperature of 22 ± 1°C. Images of the left hand were recorded using LDI followed by TI. LDF was then used on two standard locations on the fingers and back of the hand. The measurements were then repeated for a hot (37°C) and then a cold (10°C) challenge. A significant linear correlation (r = 0.960, p < 0.01, with 95% confidence limit of 0.35–0.77, n = 38) was found between LDF and LDI. However, LDF and LDI did not correlate well with TI (r = 0.577, p < 0.01, with 95% confidence limit of 0.32–0.76, n = 38). The LDI method was found to be highly reproducible (mean ± 1 SD; 625 ± 30, with coefficient of variation 5%). The blood flow and temperature distribution of skin of the hand was then recorded using TI and LDI in 10 patients (mean age ± SD, 41.7 ± 9.9) with scleroderma and eight normal volunteers (mean age ± SD, 30.6 ± 6.5). The overall mean blood flow and temperature in the hands of patients with scleroderma (mean ± SD 444 ± 265 flux, 29.3 ± 3.3°C) was significantly (p < 0.0001) lower compared with the normal volunteers (mean ± SD, 912 ± 390 flux, 34.0 ± 3.2°). These data suggest that LDI is a useful method of assessment of skin blood flow which truly is non-invasive and has the major advantage of studying a much wider area of skin than other available techniques.

Key Words: Comparative study; Laser Doppler imager; Laser Doppler flowmeter; Thermographic imaging; Regional blood flow; Non-invasive; Scleroderma.

Introduction

Changes in local microcirculatory blood flow (tissue perfusion) play a key role in a variety of clinical circumstances including arteriosclerosis, vasospastic conditions, diabetes and grafting in plastic surgery. Tissue perfusion in such conditions has been studied using several methods.[1–3] However some of these techniques may themselves seriously disturb tissue perfusion whilst others have practical limitations in clinical use.[4] In general, methods for clinical study of blood flow in small vessels measure one of three physiological parameters: physical movement of blood; temperature;[5,6] and oxygen content.[7]

In this study we have assessed three non-invasive methods of measuring skin perfusion: thermographic imaging (TI); laser Doppler flowmetry (LDF); and a novel method of mapping of tissue perfusion over a specific area using a recently developed laser Doppler imaging (LDI) instrument.[8,9]

Method and Materials

Laser Doppler flowmetry

The device consists of a laser (usually helium-neon) and an optic fibre which transmits light to the surface of the tissue to be studied. The light is then scattered randomly by both static structures and by moving tissue, i.e. blood cells. Light refracted from static tissues remains unchanged in frequency, while light scattered by moving blood cells undergoes a frequency shift according to the Doppler principle.[10] Optical fibres collect some of this light at the tissue surface and return it to the photodetectors where it is analysed. LDFs are not able to measure flow in absolute units (i.e. ml/min) and most use arbitrary units of "flux",[11] which is the product of the concentration of moving red blood cells and the mean velocity of those red blood cells. This technique gives a continuous measure of erythrocyte motion in the outermost layer

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