LASER-DOPPLER IMAGING OF FOREARM SKIN PERFUSION FEATURES AND DEPENDENCE OF THE BIOLOGICAL ZERO ON HEAT-INDUCED HYPEREMIA

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INTRODUCTION

BACKGROUND: When measuring skin blood perfusion with laser-Doppler methods in a limb, a non-zero perfusion is sometimes registered even when the arterial inflow to, and venous outflow from the site of measurement is arrested using proximal cuff compression pressures well in excess of systolic blood pressure. This residual signal, known as the biological zero (BZ)[1-7], is present to some extent with both laser-Doppler flowmetry (LDF) and laser-Doppler imaging (LDI). The BZ thus contributes a confounding background signal that is not directly related to the perfusion within blood vessels. Features of the BZ, based on single-point LDF studies, show that confounding effects of the BZ are important when measuring skin areas with relatively low blood flow.

OBJECTIVES: Although the possible impacts of the BZ are well recognized there are several issues that remain unresolved. The first concerns the magnitude of the BZ that is associated with the use of laser-Doppler imaging. The perfusion profile obtained with LDI incorporates far more information than the single point method and at present there is sparse data available on the magnitude of the BZ with this method. Secondly, it is unclear as to the extent to which the magnitude of the BZ depends on the magnitude of the blood perfusion present while the BZ determination is made. Thus the specific objective of the present study was to determine the magnitude of the LDI-BZ and its relationship to various blood perfusion levels which were altered via local skin contact heating of volar forearm skin.

METHODS

SUBJECTS: Thirty postmenopausal women who were part of a larger cardiovascular study participated in this separate investigation. Subjects were evaluated after signing an institutionally approved informed consent. Average age of the group (mean ± sd) was 61.4 ± 7.4 years and were postmenopausal for 14.4 ± 8.6 years. None were taking hormone replacement therapy. Overall, the group was considered normotensive, with systolic and diastolic blood pressures of 139.2 ± 14.9 and 78.7 ± 7.9 mmHg.

SETUPS: Tests started after an interval of 20 minutes of supine rest. The LDI scan region was a standardized 7.3 cm2 rectangular area, with its center point midway between the antecubital space and the wrist on the right volar forearm. A blood pressure cuff was placed on the right arm for later use to produce a suprasystolic occlusion (systolic + 50 mmHg) to obtain the biological zero (BZ). The LDI (Moor Instruments) was positioned so that that the center of its scan was at the center of the target area with a vertical distance from the skin surface of 30 cm. Scans were done at 4 ms/pixel and a 0.25-15 KHz bandwidth.

METHODS (CONTINUED)

PROTOCOL SEQUENCE: Three LDI scans were done; a baseline for non-heated skin, a heat-scan initiated immediately after the central portion of the target area was heated to 44°C for two minutes (circular heater with a heating area of 1.1 cm²) and a 3RD scan, the BZ-scan, initiated at 1.5 minutes into a 4-minute supra-systolic arm cuff occlusion started immediately after completion of the heat-scan (fig 1).

ANALYSES: Mean skin blood flow (SBF) in target areas were analyzed for non-heated, heated and occluded (BZ) conditions with increasing concentric areas (0.5, 1, 1.5, 2, 3, 4, 5 and 7 cm²) surrounding the midpoint of the heated area (fig 2). Thus, a range of SBF magnitudes were obtained for each heat-scan. For each area, SBF was determined and compared between non-heated, heated and occluded conditions. The BZ was determined in relation to the heated SBF for each area. In addition, for baseline and BZ scans, a separate 0.5 cm² area, distant from the center of heat area, was used to estimate BZ in relation to non-heated baseline SBF.

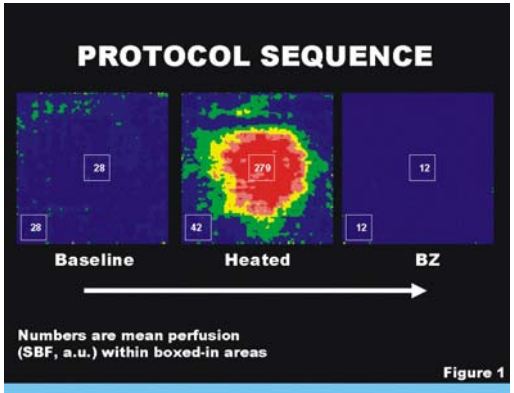


Figure 1

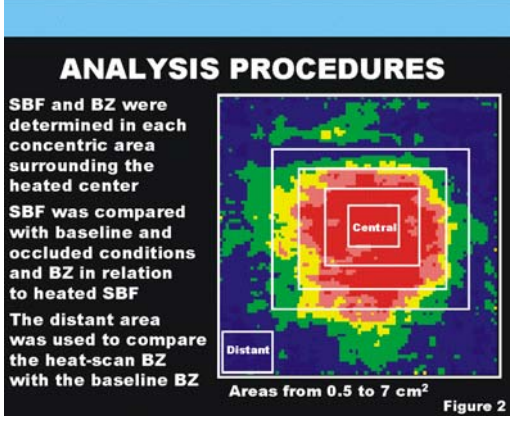


Figure 2

RESULTS

FOREARM PERFUSION

Baseline LDI perfusion (Q,a.u.) was independent of sample area (fig 3), with an average across all subjects and areas of 45.6±22.4 a.u. Heated SBF was least (158.3±61.4) for largest area and greatest (366.3±117.3 a.u.) for the smallest area.

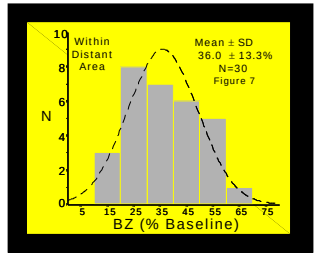
BZ of heated skin had its lowest value (16.3±6.2 a.u.) for the largest area and largest value (22.6±17.3 a.u) for the central area. SBF and BZ progressively increased as smaller concentric sample areas were used (fig 4). Overall, heat-induced perfusion within the central area increased above baseline by a factor of 10.2 ± 5.8 and the distant area SBF increased by a factor of 2.2 ± 0.4.

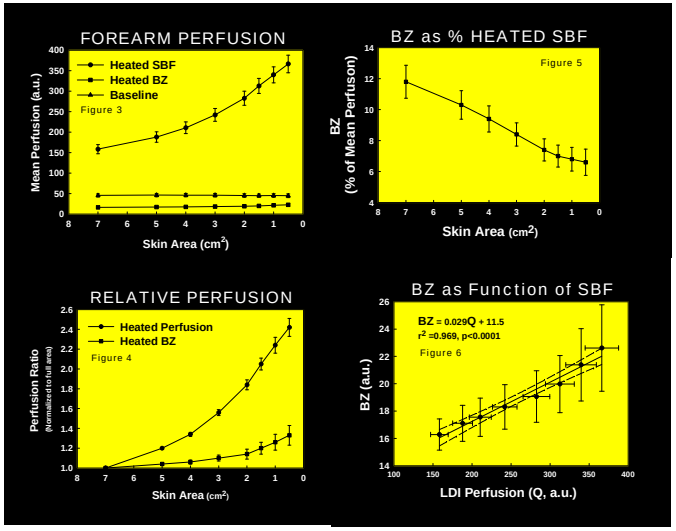
BZ to HEATED SBF

Although Q and BZ increased with decreasing area, SBF increased relatively more causing the ratio (BZ/SBF) to decrease (fig 5). The least ratio (6.6±4.6%) was in the central area and the largest (11.8±5.8%) for the least heated SBF (largest area). Overall,the relationship between BZ and SBF may be described by a linear regression equation (fig 6)

BZ to BASELINE SBF

Baseline SBF in the distant 0.5 cm2 area was insignificantly different from that in measured within the full 7 cm² baseline. But, BZ was 36.0±13.3% of baseline (fig 7) and was significantly greater than the baseline SBF (38.1±19.5 vs. 11.9±3.3 a.u., p<0.001).





CONCLUSIONS

SBF HYPEREMIA

- BZ of LDI increases with heat-induced SBF hyperemia, but the increase is small relative to SBF changes that occur
- Thus, BZ's confounding effect can be handled by subtraction of a single BZ value
- The BZ value to use may be obtained during or after hyperemia with small error when quantifying absolute hyperemic perfusion
- But, if hyperemic responses are evaluated relative to resting baseline, then the BZ of the resting state should be used to avoid substantial overestimation of the response.

RESTING SBF

For resting SBF in forearm skin, and other regions with low basal perfusion, a BZ adjustment to LDI perfusion data is fully indicated to compare groups or treatments If BZ values can not be made, or for clinical reasons should not be made, then detecting differences between groups is limited by the potentially substantial BZ confounding effect

Dr. Mayrovitz welcomes comments and queries. He may be contacted at: mayrovit@nova.edu

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