Forearm Skin Tissue Dielectric Constant: Effect of Changes in Vascular Volume and Skin Blood Perfusion

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Background

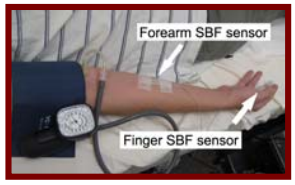
Measurements of local tissue dielectric constant (TDC) via the open-ended coaxial probe method are useful non-invasive measures of local tissue water[1-6]. The method permits assessment and tracking of changes in skin tissue water in many situations including lymphedema[7] and other conditions[8-12]. The operating principle depends on the direct relationship between TDC values and fluid content within measured tissue to effective depths up to about 5 mm below the epidermal surface. This depth includes dermal tissues as well as vascular structures so there is a question as to affects of blood volume and skin blood flow (SBF) on TDC values obtained. Our objective is to determine the extent to which local blood volume and SBP effect measured TDC values.

Methods

TDC values to a depth of about 1.5 mm and SBF to a similar depth via laser-Doppler flowmetry were measured on the anterior forearms of 20 young adult healthy supine subjects (10 male) under two test conditions. Test 1 was done with the arm horizontal and then passively raised to about 90° for 5 minutes. Test 2 was done with the arm horizontal before and during a 5 minute upper arm cuff compression to a pressure of 50 mmHg. SBF was also measured on the 3rd finger pad during all maneuvers. The forearm target site was 8 cm distal to the antecubital fossa.

Pictured above: A TDC measurement taken by the experimenter with the arm at rest and BP cuff inflated to 50 mmHg.

Pictured below: SBF measurements taken passively with the arm at rest and BP cuff inflated to 50 mmHg.



Results

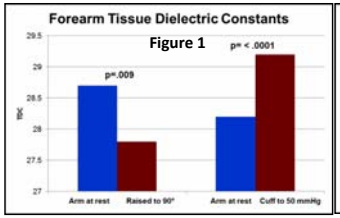


Figure 1. TDC measured for Test 1 and 2 maneuvers. There is a small but statistically significant decrease in TDC with arm raising (Test 1) and a small but statistically significant increase in TDC with application of 50 mmHg pressure proximal to the TDC measurement site (Test 2).

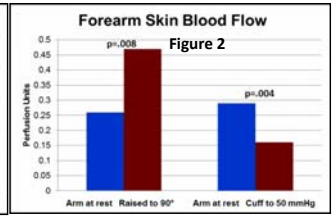


Figure 2. Skin blood flow (SBF) at the forearm site measured by laser-Doppler flowmetry. SBF was significantly increased with arm raising (Test 1) and significantly decreased with application of 50 mmHg pressure to the bicep (Test 2).

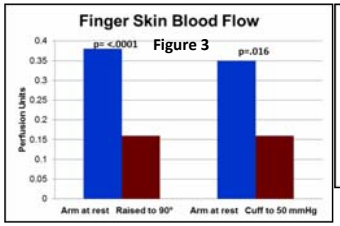


Figure 3. SBF at the distal middle finger site for the Test 1 snf 2 maneuvers. SBF was significantly decreased in value with both arm raising (Test 1) and with application of 50 mmHg of pressure to the bicep (Test 2).

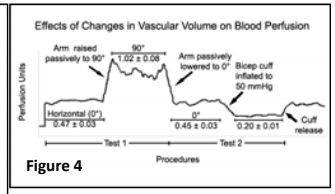


Figure 4. Tracking forearm SBF values as Test 1 and Test 2 maneuvers are performed sequentially for one subject. SBF values are elevated with arm raising (Test 1); following a return to baseline when the arm is lowered, SBF values are decreased with application of 50 mmHg of pressure to the bicep (Test 2).

	Arm horizontal (baseline)	Arm vertical	Percent change
TDC	28.7 ± 2.9	27.8 ± 2.5	-3.1%
SBF (Forearm)	0.26 ± 0.13	0.47 ± 0.33	+103 ± 156%
SBF (Finger)	0.38 ± 0.24	0.16 ± 0.13	-27.77 ± 151.2%

Table 1. Changes with arm elevation to a vertical position (Test 1)

	Arm cuff 0 mmHg	Arm cuff 50mmHg	Percent Change
TDC	28.2 ± 2.8	29.2 ± 3.1	+3.5%
SBF (Forearm)	0.29 ± 0.23	0.16 ± 0.07	-39.5*** ± 13.1%
SBF (Finger)	0.35 ± 0.29	0.16 ± 0.17	-58.64 ± 19.68%

Table 2. Changes with inflation of the biceps cuff to 50 mmHg (Test 2)

Conclusions

Over the wide range of blood volume and SBF shifts associated with the employed maneuvers a 3.0-3.5% change in TDC values was observed. This suggests that for most clinical evaluation and tracking purposes in which such large shifts in blood volume and perfusion are unlikely, the confounding effects of variations in SBF or volume are inconsequential.

From the physiological perspective, the decrease in TDC with arm raising is consistent with a gravity-dependent drainage in vascular volume and the increase in TDC with application of cuff pressure is consistent with reduced drainage from vascular compression.

The finding of an increase in forearm SBF agrees with previous work suggesting that venous emptying leads to arteriolar vasodilation. The decrease in SBF at forearm with cuff pressure and at finger with arm raise is consistent with a perfusion pressure reduction accompanying these maneuvers.

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