Effect of Changes in Vascular Volume and Skin Blood Perfusion on Forearm Skin Tissue Dielectric Constant Measured at 300 MHz

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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. The method permits assessment and tracking of changes in skin tissue water in many situations including lymphedema and other edematous conditions. 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. Since this depth includes skin structures and vasculature the effect of blood volume and skin blood perfusion (SBP) on TDC values is unclear.
Objective: Evaluate the effects of local blood volume and SBP changes on TDC values.
Methods: TDC values to an effective depth of 1.5 mm were measured and SBP to a similar depth were measured via laser-Doppler flowmetry 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^{o} 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. SBP was also measured on the 3^{rd} finger pad during all maneuvers. The forearm target site was 8 cm distal to the antecubital fossa.
Results: For test-1, horizontal TDC values of 28.7 ± 2.9 decreased slightly but significantly on arm raising to 27.8 ± 2.5, $p<0.01$. For test-2, horizontal TDC values of 28.2 ± 2.8 increased slightly but significantly to 29.2 ± 3.1, $p<0.01$ during upper arm compression. At the forearm site SBP significantly increased during test-1 maneuver (+102.6 ± 156%, $p<0.001$ and decreased during test-2 maneuver (-39.5 ± 13.1%, $p<0.001$). During both test maneuvers finger SBP significantly decreased ($p<0.001$) by -54.2 ± 32.1% for test-1 and -53.3 ± 27.7% for test-2.
Conclusions: Over the wide range of blood volume and SBP 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 raised is consistent with a perfusion pressure reduction accompanying these maneuvers.