Skin Tissue Dielectric Constant Measurements as a Non-Invasive Method to Detect Early Lymphedema in Women Treated for Breast Cancer

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Background and Goals

Our main goal is to determine the utility of local skin water measurements using the tissue dielectric constant (TDC) to detect subclinical lymphedema in women treated for unilateral breast cancer. These women are at-risk for developing breast cancer treatment-related lymphedema but often lymphedema is not recognized by the patient, or is ignored, until gross manifestations of swelling and functional limitations or other complications are present. The hypothesis is that quantitative measurements of skin water will uncover incipient lymphedema for which there are not yet patient or clinically recognized symptoms thereby prompting earlier and more effective treatment.

Methods

To test the hypothesis 46 women who were treated for unilateral breast cancer were evaluated 6-60 months after their surgery. Bilateral TDC measurements were done on hand dorsum, anterior forearm, biceps and shoulder and lateral thorax using a small probe that contacts the skin for about 10 seconds. Ages (mean±SD) were 63.3±11.3 years and surgery was 32.6±23.0 months prior to their evaluation.

TDC Measurement Method

The method is based on the principle that the TDC is directly related to the amount of free and bound water contained in the measuring volume[1-4]. The device used is this study was the Moisture MeterD (Delfin Technologies). The TDC of specific target areas is determined using a coaxial probe that gently contacts the skin for about 10 seconds. The probe, which is connected to a control and display device, measures the TDC at a frequency of 300 MHz. At this frequency the TDC is an index of both free and bound water. The depth of the measurement depends on the probe size, with larger diameter probes penetrating deeper. The output parameter is the TDC value that has a range of 1 to 80. For reference, pure water has a value of about 78.5. For this study a probe with an effective measurement depth of 2.5 mm was used. TDC measurements have been previously used to assess skin tissue water in various conditions and at various anatomical sites[5-9]

Measurement Procedures

After administering the informed consent a questionnaire was completed by the subject. It consisted of questions related to their perception of possible lymphedema symptoms. The subject then lied down on an exam table for measurements. TDC values were measured at five sites: (1) dorsum of the hand at the web space between the 1st and 2nd fingers, (2) anterior forearm along the midline 8 cm distal to the antecubital crease, (3) medial biceps 8 cm proximal to the antecubital crease, (4) anterior shoulder and (5) lateral thorax 10 cm below the axila. Arm girths were measured with a calibrated tape measure at 6 cm intervals from wrist to axilla and are used to calculate arm volume.

Measurements Illustrated


Figure 1. Girth Measurement


Figure 4. Biceps TDC Measurement


Figure 2. Hand TDC measurement


Figure 5. Shoulder TDC measurement


Figure 3. Forearm TDC measurement


Figure 6. Axilla TDC measurement

Analysis

Control arm volumes (VA and VC) were determined from girth measurements taken at 4cm intervals from wrist to axilla. Percentage edema volume (%EVOL) was determined as 100(VA-VC)/VC. At-risk/control arm TDC ratios were determined for each site and compared in patient subsets grouped according to their %EVOL.

Main Results

Results show that at the time of evaluation, 34.9% of patients had %EVOL greater than 5% and 15.2% had %EVOL greater than 10%. These levels are threshold-limits often used to define lymphedema presence. Biceps TDC ratios for patients with %EVOL below and above these thresholds were 0.993 ± 0.082 vs. 1.210 ± 0.376, p=0.006 (Mann-Whitney) for the 5% threshold and 1.009 ± 0.099 vs. 1.396 ± 0.508, p=0.027 for the 10% threshold. At no other site were TDC values significantly different between low and high %EVOL patient subsets. However, both biceps and forearm TDC ratios positively correlated with the number of axillary nodes removed as shown in FIGURE 7. For patients with %EVOL >5%, Pearson correlation coefficient r-values of forearm and biceps ratios vs. number of nodes removed were respectively 0.764 (p<0.001) and 0.692 (p<0.01). TDC ratios (at-risk/control) are shown in FIGURE 9 for the subset of patients in whom the %EVOL was greater than 5%. Arm volume ratios showed no significant relationship to either nodes removed or time from surgery. The most widely reported symptoms (FIGURE 8) were arm numbness, tingling, or ache each self-reported by 43.8% of patients with %EVOL >5%. Patients with %EVOL>10% reported more symptoms.

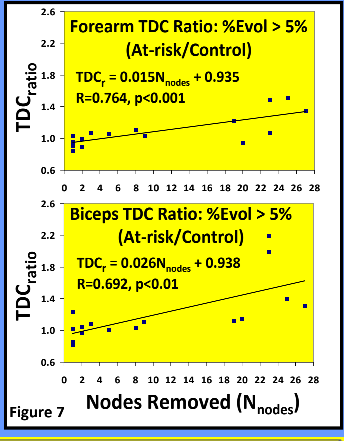


Figure 7

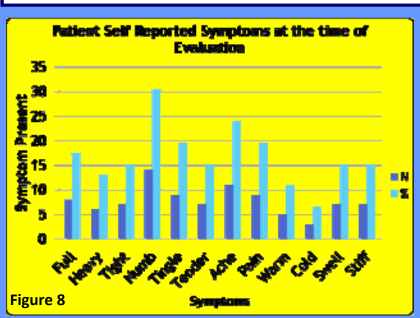
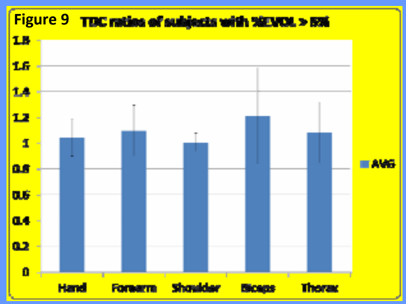


Figure 8

Figure 9


Conclusions

These findings show that the biceps TDC ratio may be the parameter most indicative of a useful measure for early lymphedema detection, although both biceps and forearm ratios increase with increasing number of nodes removed.

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