

*TECHNICAL REPORT***LOCAL TISSUE WATER CHANGES ASSESSED BY  
TISSUE DIELECTRIC CONSTANT: SINGLE MEASUREMENTS  
VERSUS AVERAGING OF MULTIPLE MEASUREMENTS**

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**ABSTRACT**

*Previous reports describe the use of average tissue dielectric constant (TDC) measurements to assess local tissue water and its change. Our goal was to determine if a single TDC measurement could be used in place of the average of multiple measurements. The comparison criteria used to test this was the extent to which single and averaged measurements yielded similar TDC values in both normal and lymphedematous tissue. Measurements were made on both ventral forearms to a depth of 2.5 mm in 10 women with unilateral arm lymphedema. The main results showed that the 95% confidence interval for differences between single and averaged TDC values was less than  $\pm 1$  TDC unit for both normal and lymphedematous arms. This finding strongly suggests that for most, if not all, clinical evaluations, suitable assessments can be made using a single TDC measurement.*

**Keywords:** lymphedema measurement, edema measurement, skin water lymphedema treatment, dielectric constant, tissue water, arm lymphedema

Recent work indicates that assessing local tissue water based on measurements of

the tissue dielectric constant (TDC) is a useful discriminator of lymphedema in patients with unilateral postmastectomy lymphedema (1) and to detect changes subsequent to manual lymphatic drainage (MLD) therapy (2). In these studies, TDC measurements were done at least in triplicate and then averaged to help reduce measurement variance potentially associated with a single measurement (1-3). This strategy is useful but it also triples the time required for each assessment site. Further, averages of repeated measurements is only better than a single measurement if the results or reproducibility obtained are significantly different between them (4). If the amount of difference of a single TDC measurement compared to averaging triplicate measurements were known, than an informed decision as to which approach to adopt for clinic applications could be made. Thus, the present study sought to determine and compare differences between single and triplicate TDC measurements with respect to outcome values obtained.

**METHODS**

Ten women (ages  $71.2 \pm 14.1$ ; mean  $\pm$  SD) who had unilateral arm lymphedema subsequent to breast cancer related surgery and/or radiation treatment were evaluated

**TABLE 1**  
**TDC Values for Lymphedematous Group**

Depth (mm)	Non-edematous Arm (n=10)			Edematous Arm (n=10)		
	TDC <sub>1</sub>	TDC <sub>AVG</sub>	95% CI of difference	TDC <sub>1</sub>	TDC <sub>AVG</sub>	95% CL of difference
2.5	25.0±2.8	25.3±3.0	-0.76 to 0.16	41.0±9.0	41.1±8.8	-0.53 to 0.39
Data entries are mean ± SD. Differences between TDC <sub>1</sub> and TDC <sub>AVG</sub> for edematous and non-edematous arms were statistically insignificant. TDC values of edematous arms were significantly greater than for non-edematous arms (p<0.001).						

after signing Institutional Review Board approved informed consents. The device used was the MoistureMeter-D, (Delfin Technologies Ltd, Kuopio, Finland). It consists of a probe connected to a control unit that displays the tissue dielectric constant when the probe is placed in contact with the skin. The physics and principle of operation has been well described (5,6). Pure water has a value of about 78.5, and the display scale range is 1 to 80. The probe used has an effective penetration depth of 2.5 mm.

Measurements were made on volar (ventral) forearms of both arms 6 cm distal to the antecubital crease with subjects supine. Measurements started after the subject had been lying for 10 minutes and were made in triplicate-pairs alternating between body sides. The time required to obtain a single measurement was about 10 seconds.

For analysis, two TDC parameters were used: the first value obtained and the average of the triplicate TDC values. These parameters, designated as TDC<sub>1</sub> and TDC<sub>AVG</sub>, respectively, provided 10 (TDC<sub>1</sub>-TDC<sub>AVG</sub>) comparison pairs for each arm. This approach to comparing a single measurement to an average of repeated measurements is similar to that carried out for blood pressure measurements (4). Differences between single and averaged TDC values of lymphedematous and non-lymphedematous arms were tested with the nonparametric Mann-Whitney U

test using a p-value <0.05 as criteria for a significant difference.

### RESULTS

The main results are summarized in *Table 1*. Differences between TDC<sub>1</sub> and TDC<sub>AVG</sub> values were insignificantly different from each other. This was true for edematous and non-edematous arms although absolute TDC values for lymphedematous arms were significantly greater than for contralateral arms (p<0.001). Correlations between single and averaged values were very high, being 0.998 for the nonedematous arm and 0.978 for the edematous arm. In contrast, there was no significant relationship between TDC values obtained from the edematous arm and those obtained from the contralateral arm for either single or averaged measurements.

### DISCUSSION

The goal of this study was to determine the suitability of using a single tissue dielectric constant measurement to assess local tissue water as compared to using the average of multiple measurements. The comparison criteria used to test this was the extent to which single and averaged measurements yielded similar TDC values in both normal and lymphedematous tissue. The main results show that the 95%

confidence interval for differences between single and averaged TDC values is less than  $\pm 1$  TDC unit for each condition measured. This finding strongly suggests that for most, if not all, clinical evaluations, suitable assessments can be made using a single measurement. These findings specifically apply to measurements done on the forearm, which was chosen because of its relevance to assessments associated with breast cancer treatment-related lymphedema. Because of the versatility of the measurement method to assess relative local tissue fluid at virtually any surface body site, it would be of interest to further investigate and compare single vs. average measurement approaches at other clinically relevant sites.

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