

# FOREARM SKIN WATER ASSESSED BY TISSUE DIELECTRIC CONSTANT

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## BACKGROUND and GOALS

Skin tissue dielectric constant (TDC) measurements have been used to estimate local tissue water (LTW) and its change under a variety of conditions including skin irritation skin irradiation, hemodialysis, post cardiac surgery changes, weight loss, menstrual cycle and most extensively to assess lymphedema<sup>1-7</sup>. TDC values in these studies were measured at a frequency of 300 MHz via a coaxial line reflection method in which TDC values depend on tissue water content. Effective measurement depth depends on the size and geometry of the coaxial probe in contact with the skin so that TDC values obtained reflect the composite tissue to varying measurement depths depending on probe used. The depth dependence of LTW over a range from 0.5 mm to 5.0 mm has been investigated in the forearms of persons with lymphedema and more recently in non-edematous arms. Results of these studies indicate a decrease in LTW with increasing measurement depth. However, since these previous studies utilized a single standardized forearm site for measurements the extent of spatial uniformity of forearm TDC values as reflective of LTW is currently unknown. Such information would be useful for a variety of purposes not the least of which is the fact that forearm skin is a widely used target for biophysical measurements. Thus the goal of this research was to use TDC measurements to determine and characterize the extent of spatial variations of LTW in normal forearm skin tissue.

## SUBJECTS

Thirty females participated after signing a University Institutional Review Board approved informed consent. Women were chosen because of the interest in the use of the TDC method for lymphedema assessment. Age (mean ± SD) was 27.4 ± 6.5 years (range 22-48 years). Body mass index (BMI) for the group was 22.9 ± 3.4 Kg/m<sup>2</sup> (range 17.1 - 35.8 Kg/m<sup>2</sup>). With respect to BMI classification, 2 (6.7%) of subjects were underweight (BMI <18.5 Kg/m<sup>2</sup>), 22 (73.3%) were normal (BMI 18.5 - 25 Kg/m<sup>2</sup>), 5 (16.7%) were overweight (BMI 25-29.9 Kg/m<sup>2</sup>) and 1 (3.3%) was obese (BMI ≥ 30 Kg/m<sup>2</sup>). The right hand was the self-reported dominant hand in 25 subjects (83.3%) and the left was dominant in 5 (16.7%).

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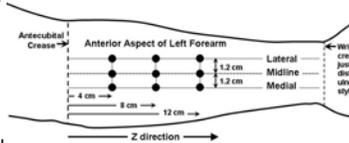
## TDC MEASUREMENT METHOD

The device used to measure TDC was the MoistureMeter-D. It consists of a cylindrical probe connected to a control unit that displays the TDC value when the probe is placed in contact with the skin. A very low intensity 300 MHz signal is generated within the control unit and is transmitted to the tissue via the probe that is in contact with the skin. The probe acts as an open-ended coaxial transmission line. The portion of the incident electromagnetic wave that is reflected depends on the tissue dielectric constant, which itself depends on the amount of free and bound water in the tissue volume through which the wave passes. Reflected wave information is processed and the dielectric constant is displayed. For reference, pure water has a value of about 78. The effective measurement depth depends on probe dimensions, with larger spacing between inner and outer conductors corresponding to greater penetration depths. In the present study three different probes were used with effective measurement depths of 2.5, 1.5 and 0.5 mm.



## MEASUREMENT PROCEDURE

The subject was seated in a comfortable chair that had an attached padded support upon which the subject rested her arms with hands positioned palm up to expose the anterior surface of both forearms. Prior to the start of measurements, nine spots on the non-dominant forearm were marked with a small dot using a surgical pen. These dots served as the center points for subsequent TDC measurements. Using a template, three reference sites were first marked along the forearm midline at 4, 8 and 12 cm distal



to the antecubital crease (AC) for lateral TDC measurements. Marks were then made 1.2 cm lateral and 1.2 cm medial from each of the three midline marks. A TDC measurement was obtained by placing a probe in contact with skin for about 10 seconds. For 2.5 and 1.5 mm depth probes, single measurements were made first along the midline starting at the site located 4 cm from the AC and progressing to the 8 and 12 cm distal sites. This sequence was repeated for medial and then lateral sites. The measurement set was repeated twice more to get triplicate measurements at each site. The time between successive measurements at each site was about 2.5 minutes. Triplicate measurements were then made along the midline only (3 sites) using a probe with a 0.5 mm measurement depth. For each probe and site the triplicate TDC average and coefficient of variation was determined. Arm girth was measured with a tape measure and skin temperature measured with an infrared thermometer.

## MAIN RESULTS

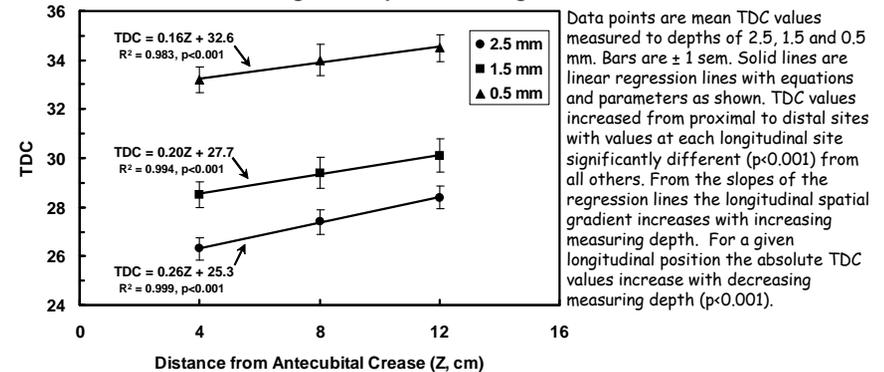
### TDC Values among sites for 2.5 and 1.5 mm measurement depths

Z (cm)	Measurement Depth (mm)					
	2.5 mm			1.5 mm		
Circumferential Position	4	8	12	4	8	12
Midline	26.3±2.8* [1.5±1.5]	27.4±3.4* [1.2±1.0]	28.4±3.7* [1.3±1.2]	28.5±2.5 [1.5±1.2]	29.4±2.7 [1.1±0.7]	30.1±2.5 [1.4±0.8]
Medial	26.3±3.6* [1.5±1.3]	26.9±3.7* [1.3±0.9]	28.1±4.1* [1.6±1.9]	28.2±2.5 [1.9±1.1]	28.7±2.6* [1.6±1.0]	29.4±2.7* [1.4±1.0]
Lateral	27.9±4.0* [1.2±1.0]	28.1±3.1* [1.0±0.6]	28.1±3.3* [1.7±1.9]	29.3±2.9* [1.4±0.7]	29.9±2.7 [1.4±1.2]	30.0±2.7 [1.5±1.0]

Table entries are TDC values (mean ± sd, n=30). Bracketed values [ ] are coefficient of variations of triplicate measures. Z is the longitudinal distance along the forearm. \*For all sites, TDC values measured to a 2.5 mm depth are less than at corresponding sites measured to a 1.5 mm depth (p<0.001).

At midline and medial positions TDC values for both measurement depths progressively increase with increasing Z (p<0.001). Lateral position values do not significantly differ with Z for either measurement depth. Circumferential differences among TDC values were variable with the asterisk (\*) denoting values that were significantly different (p<0.01) from values at the other two circumferential positions

### Midline TDC values vs. longitudinal position along the forearm



Data points are mean TDC values measured to depths of 2.5, 1.5 and 0.5 mm. Bars are ± 1 sem. Solid lines are linear regression lines with equations and parameters as shown. TDC values increased from proximal to distal sites with values at each longitudinal site significantly different (p<0.001) from all others. From the slopes of the regression lines the longitudinal spatial gradient increases with increasing measuring depth. For a given longitudinal position the absolute TDC values increase with decreasing measuring depth (p<0.001).

## DISCUSSION AND CONCLUSIONS

In summary, the composite findings demonstrate an increase in TDC values along the forearm from proximal to distal sites most prominent at midline and medial positions and also demonstrate differences among circumferential positions more prominent at proximal than distal sites. Since many skin related dermatological and biophysical studies utilize the forearm as a test target such differences may be important considerations in experiment design and data interpretation since TDC values at least in part are reflective of the local tissue water. In addition, although the variation in mean TDC values among the measured sites is less than 10% such differences may be of importance when evaluating local tissue water changes using the TDC method in patients with arm lymphedema that is present in variable arm anatomical locations.