TISSUE DIELECTRIC CONSTANT AS AN INDEX OF LOCALIZED ARM SKIN WATER:

Differences Between Measuring Probes and Genders

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Background and Purpose

There is an important need to conveniently obtain non-invasive quantitative estimates of skin tissue water content in many conditions especially those those related to evaluating local edema and lymphedema. One method that is capable of measuring at any anatomical site relies on the measurement of the skin tissue dielectric constant (TDC) at a frequency of 300 MHz. Since the TDC value is largely dependent on the tissue water content, the TDC value itself can be used as an index of local tissue water content and its subsequent change that might accompany therapy.

More recently, a fully portable compact device has been developed that integrates the probe and control box features into a single hand-held apparatus, which might be more readily usable in clinical settings. However, the relationship between TDC values measured with this compact system to those measured with multi-probe system is currently unclear. Clarification of these relationships would facilitate comparisons of TDC data already in the literature and allow for future data comparisons.

Since the new compact device has the capability of measuring to one depth, an important aspect of its characterization is to determine its effective measurement depth. Further, since differences in TDC values between male and female (1) and differences between anatomical sites (2,3) have been described, possible effects of such differences on compact probe TDC values needs to be assessed and characterized.

Thus, our specific aims were to compare TDC values obtained from multi-probe device and the compact probe with respect to potential differences in

- Male-female TDC values
- Effective measurement depth
- Arm site TDC values
- TDC values in females with and without breast cancer

Method

Sixty four mostly young and self-described healthy adults participated in this study (32 male and 32 female) along with 12 female patients who were awaiting surgery (within 2 weeks) for breast cancer.

Method – TDC Measurement Devices

The multi-probe device used to measure TDC was the MoisutreMeterD (MMD) and the compact device used was the MMD Compacts (MMDC) (Delfin Technologies). The MMD consists of a cylindrical probe connected to a control unit that displays the TDC values when the probe is placed in contact with the skin (Figure 1A), transmitting a 300 MHz signal and acting as an open-ended coaxial transmission line (4,5). The portion of the incident electromagnetic wave that is reflected depends on the dielectric constant of the tissue, which itself depends on the amount of free and bound water in the tissue volume through which the wave passes. For reference, pure water has a value of about 78.5 and the display scale range is 1 to 80. In the present study, probes with effective measurement depths of 1.5 mm and 2.5 mm were mused for the multi-probe measurements. The MMDC probe electrode dimensions are arranged so that the effective penetration depth consists of skin and the upper subcutaneous fat layer. The dimensions of the MMDC electrodes and spacing are similar to the MMD probe, which has an effective penetration depth of 2.5 mm.

Measurement Procedures

All measurements were done after a 10 minute acclimation rest interval with the subjects seated. TDC measurements were made on standardized sites on the anterior part of both forearms and both biceps.

- The MMDC contacts the skin and is held in position for about 10 seconds and an audible signal is given off, indicating completion of the measurement.
- In the healthy subject group, TDC measurements at each site were made first with the 2.5 mm depth probe (Figure 1B), followed by the measurements of the 1.5 mm depth probe (Figure 1A), and lastly by the compact probe (Figure 1C).
- In the patient group, TDC measurements were made only using the compact probe, but at the corresponding sites used in the healthy group.
- After TDC measurements, arm girth (circumference) at the measurement sites were determined using a Gulick-type tape measure

Figure 1: Measurement devices and probes. 1A) MMD unit with probe in contact with forearm skin; 1B) Compact MMDC unit; 1C) Probes shown from measuring surface end. Probes A and B are used with the MMD unit and have effective measurement depths of 1.5 mm for A and 2.5 mm for probe B. Probe C is the self contained MMDC unit.

Analysis

Dominant and non-dominant arm TDC measurements were averaged to obtain a single averaged TDC value (forearm and biceps separately).

- Possible differences among TDC measurements obtained with 1.5, 2.5 and compact probes on healthy group were tested using a general linear model (GLM) with repeated measures for each measure.
- Possible differences between male and female TDC values were tested using independent t-tests with a p-value <0.01 taken as indicating a significant difference.
- Possible differences in TDC values between arms were tested directly by comparing dominant vs. non-dominant absolute TDC values (paired T-test)
- The ratio of TDC values (dominant/non-dominant) was calculated for each subject and compared by probe, site and gender.
- TDC measurements made only on female arms with the corresponding anatomical sites were tested for differences using independent t-tests.

	Forearm: Dominant / Non-Dominant Arms			Biceps: Dominant / Non-Dominant Arms		
Probe	Female	Male	p-value	Female	Male	p-value
1.5 mm	0.993 ± 0.050	1.030 ± 0.057	0.070	1.000 ± 0.053	1.006 ± 0.053	0.648
Compact	1.000 ± 0.054	1.023 ± 0.064	0.123	1.004 ± 0.064	1.003 ± 0.066	0.966
2.5 mm	0.993 ± 0.051	1.016 ± 0.050	0.075	1.001 ± 0.054	0.996 ± 0.043	0.666
Girth ratio	1.015 ± 0.027	1.0160 ± 0.025	0.930	1.005 ± 0.021	1.008 ± 0.004	0.528

Table 1: Dominant/Non-dominant arm TDC ratios by gender and effective measurement depth. There was no significant difference in thes ratios between genders or site at any depth nor was there any significaatn difference among depths for wither gender.

Main Results

HEALTHY SUBJECTS

- TDC values at depths of 1.5 and 2.5 mm using the MMDand TDC values measured with MMDC were all significantly greater in males than females ($p<0.001$) at both forearm and biceps site (graph 1).
- Comparisons of differences among probes showed that for males and for females, TDC values obtained with each probe were significantly different ($p<0.001$) from each other with TDC values progressively decreasing from those obtained with the 1.5 mm probe to the compact probe to the 2.5 mm probe (table 1)
- Percentage differences in TDC values between the compact probe and the 2.5 mm depth probe were for the forearms and biceps respectively 5.4±3.8% and 6.4±5% for females and 5.7% ± 5% and 4.7% ± 6.1% for males

BREAST CANCER PATIENTS

- TDC values (dominant vs. non-dominant) on the forearm were found to be 30.5±4.4 vs 30.7±4.1 ($p=0.817$) and for biceps were 29.5±3.9 vs. 30.4±3.9 ($p=0.758$).
- TDC ratios determined with the compact probe (dominant/non-dominant) at the forearm were 0.994±0.06 and at the biceps were 0.97±0.045 with both ratios being insignificantly different form corresponding ratios determined for the healthy groups of females.
- The results suggest that at least at this early stage the presence of the breast cancer did not alter the ratio.

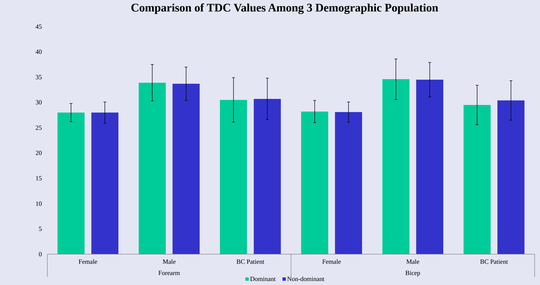

Figure 7: Comparison of TDC values in dominant vs. non-dominant hand among different demographs

Conclusions

- TDC Values in healthy male arms are significantly greater than in healthy female arms
- TDC values for both genders are less at deeper effective measurement depths
- TDC values measured with the compact probe are between those measured to 1.5 and 2.5 mm depths and exceeds the 2.5 mm probe depth value by about 5.6%
- Inter-arm TDC values and ratios (dominant/non-dominant) did not significantly differ with respect to probe, site or gender in healthy male and female subjects or between healthy females and those with breast cancer
- Absolute TDC values and inter-arm ratios measured with the compact probe in breast cancer patients did not significantly differ form those measured in younger healthy female

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