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LOCALIZED TISSUE WATER CHANGES ACCOMPANYING ONE MANUAL LYMPHATIC DRAINAGE (MLD) THERAPY SESSION ASSESSED BY CHANGES IN TISSUE DIELECTRIC CONSTANT INPATIENTS WITH LOWER EXTREMITY LYMPHEDEMA

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ABSTRACT

Previous reports described the utility of assessing local tissue water via tissue dielectric constant (TDC) measurements. Our goal was to determine the suitability of this method to evaluate lymphedema changes. For this purpose, we measured changes in TDC produced by one MLD treatment in 27 legs of 18 patients with lower extremity lymphedema. TDC values were measured to a depth of 2.5 mm at the greatest leg swelling site before and after one MLD treatment. Girth at the target site was measured with a calibrated tape measure. TDC values, which range from 1 for zero water to 78.5 for all water within the sampled volume, were measured four times and the average used to estimate local changes. Results showed that in every case the post-treatment TDC was reduced from its pre-treatment value with percentage reductions (mean SD) of -9.8 ± 5.64% (p<0.0001). Girth changes were smaller being -1.5 ± 1.93% (p<0.01). We conclude that since TDC measurements reflect changes to a depth of about 2.5 mm whereas girth measurements reflect conditions of the entire cross-section, TDC assessment may be more sensitive to localized lymphedema changes. This finding suggests that TDC measurements are useful as complementary and perhaps as independent assessment methods of edema/lymphedema and treatment-related changes.

Keywords: lymphedema measurement, edema measurement, lymphedema treatment, dielectric constant, tissue water, leg lymphedema, manual lymphatic drainage, MLD

A variety of methods are available to assess overall limb edema via metric and volume measures (1-8), automated methods (9-12), and electrical impedance type methods (13-16). However, these are not generally suitable to determine local edema or edema in body parts other than the limbs. Quantitative assessment of local tissue edema could provide important and useful information not previously available to help initially assess and to track lymphedema progression in patients. Recent work has indicated that measurement of local tissue water is a useful discriminator for the presence of lymphedema in patients with unilateral postmastectomy lymphedema (17). The method's working principle is based on the fact that tissue electrical properties depend on water content which in turn affects the value of the tissue dielectric constant (18). Measurement of the tissue dielectric constant (TDC) at a suitable frequency thus provides an index of the relative tissue water (19-24). The present study sought to determine if this method could detect changes in local tissue water associated with manual lymphatic drainage in patients with lower extremity edema and if so to characterize the amount of such change attributable to a single MLD session. The null hypothesis was that there would be no significant difference between pre-treatment and post-treatment TDC values.

METHODS

Subjects

A total of 18 subjects (10 male, 8 female) with ages of 74.1 ± 13.3 (mean ± SD; range 36 to 88 years) were evaluated after signing an Institutional Review Board approved informed consent. Of the 18 subjects, 9 had bilateral lymphedema and 9 had unilateral involvement; all legs (n=36) were evaluated. To be included in this study, subjects needed to be at least 21 years of age and about to receive MLD therapy for their condition. Lymphedema duration and its extent were not factors that affected participation since the goal of this initial study was to determine the suitability of the method for assessing localized changes in a broad population.

Measurement Device

The device used in this study is the MoistureMeter-D, (Delfin Technologies Ltd, 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 have been well described (19-21,23,24). In brief, a 300 MHz signal is generated within the control unit and is transmitted to the tissue via the probe that is contact with the skin. The probe itself acts as an open-ended coaxial transmission line (21,23). 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. The reflected wave information is processed within the control unit and the relative dielectric constant is displayed. Pure water has a value of about 78.5 and the display scale range is 1 to 80. The effective penetration depth depends on the probe dimensions, with larger spacing between inner and outer conductors corresponding to greater penetration depths. In the present study the probe used had an effective penetration depth of 2.5 mm with a corresponding probe diameter of 23 mm with a conductor spacing of 5 mm.

Measurement Procedure

Measurements were done by two experienced and certified lymphedema therapists. For bilateral lymphedema cases, sites on each limb were identified as sites of maximum or near maximum swelling and were marked with a surgical pen. For unilateral cases, sites of maximum swelling on the affected limb and a corresponding anatomical site on the contralateral limb was identified and marked. For the TDC measurements, the probe was placed in contact with the skin and held in position using gentle pressure. The time required to obtain a single measurement, once the probe was placed in contact with the skin, was 7-10 seconds. Each TDC measurement was done four times with the average value of the four used to characterize the site average TDC value. TDC measurements were made prior to the start of the patient's MLD therapy session and at the end of the therapy session about one hour later. Subsequent determinations of the coefficient of variation among the four measured TDC values showed a slightly larger overall value for edematous legs (5.10 ± 2.95%) than for non-edematous legs (4.48 ± 3.01%) but the difference was not statistically significant ($p>0.40$).

Girth Measurements

Limb girth (circumference) at sites of TDC measurements was determined using a calibrated tape measure (Gulick type). Girth measurements were made prior to the start of the therapy session and at the end of the

TABLE 1
Patients with Unilateral Lymphedema – Edematous Leg Only Treated

	Pre-Treatment		Post-Treatment		Percent Changes (%)	
	Edema Leg	No Edema Leg	Edema Leg	No Edema Leg	Edema Leg	No Edema Leg
TDC	45.6±10.0[a]	35.6±11.6	41.5±10.8[b]	36.3±10.9	-9.9±6.33	+2.7±12.1
Girth (cm)	43.2±15.3[a]	37.5±12.3	42.5±15.4[a]	37.2±12.4	-1.9±1.89	-1.1±1.68

TDC is tissue dielectric constant in relative units; Girth is circumference at site of TDC measurement. [a] = p<0.01 compared to the No Edema Leg; [b] = p<0.001 compared to pre-treatment. Data entries are mean ± SD for 9 patients with unilateral lower extremity involvement.

therapy session immediately after the TDC measurements.

Analysis

Separate analyses were done for patients with unilateral involvement (n=9, 9 treated legs) and for patients with bilateral involvement (n=9, 18 treated legs). For both groups the pre- and post treatment TDC and girth values were determined, compared and tested for significant pre-to-post changes. In addition, for the unilateral cases, the affected leg values were compared to the non-affected leg values both prior to treatment of the affected leg and after treatment. A possible relationship between changes in TDC and changes in girth was tested using regression analysis of values for all treated legs (n=27). In all cases, statistical significance was inferred based on a p- value <0.05.

RESULTS

Unilateral Lymphedema Group

Results are summarized in *Table 1* (mean ± SD throughout). Prior to the MLD treatment, TDC and girth values at the target site were significantly greater (p<0.01) than for the edematous compared to the non-edematous contralateral leg. The single MLD treatment was associated with a significant reduction in local tissue water of the affected leg corresponding to a percentage decrease in TDC of -9.9 ± 6.33% (p<0.001). There were no significant changes in non-edematous leg TDC values (+2.71 ± 12.1%, NS). For both edematous and non-edematous legs, an overall small, non-significant change in girth was found after treatment that amounted to a reduction of 1.9 ± 1.89% in the edematous leg and 1.1 ± 1.68% in the contralateral non-treated leg.

Bilateral Lymphedema Group

Results are summarized in *Table 2*. The single MLD treatment of both lymphedematous legs was associated with a significant reduction in local tissue water corresponding to a percentage decrease in TDC of -9.7 ± 5.45% (p<0.0001) and a small but significant percentage change in girth (-1.4 ± 1.98%, p<0.001).

TDC vs. Girth Changes

Considering all treated legs (n=27), pre-treatment values for TDC and girth were respectively 43.2 ± 6.5 and 40.2 ± 10.5 cm. Corresponding percentage changes produced by one MLD treatment were -9.75 ± 5.64% and -1.50 ± 1.93% respectively with the differential effect being highly significant (p<0.0001). Regression analysis of paired

TABLE 2
Patients With Bilateral Lymphedema – Both Legs Treated

	Pre-treatment	Post-treatment	Percent Changes (%)
TDC	42.1±3.7	38.0±4.3[c]	-9.7±5.45[c]
Girth (cm)	38.6±7.2	38.1±6.8[b]	-1.7±1.98[b]

TDC is tissue dielectric constant in relative units; Girth is circumference at site of TDC measurement. [b]=p<0.001 and [c]=p<0.0001 compared to pre-treatment. Data entries are mean ± SD for 9 patients with bilateral lower extremity involvement

TDC and girth changes for these treated legs showed no significant correlation (R2=0.07, p>0.2).

DISCUSSION

The present study is the first to investigate the possibility of using the tissue dielectric constant method and device to evaluate leg tissue water and therapy-related changes in local tissue edema in patients with lower extremity lymphedema. Results demonstrate that TDC values of lymphedematous legs are significantly greater than for non-edematous legs with values found for lymphedematous legs (43.2 ± 6.5) being similar to those previously reported for 18 lymphedematous arms (41.2 ± 7.9) (17). The results further show that a single MLD treatment resulted in slightly less than a 10% reduction in TDC for both unilateral and bilateral leg conditions whereas percentage reductions in girth were 1.5%. We believe that since TDC measurements reflect changes to a depth of about 2.5 mm whereas girth measurements reflect conditions of the entire cross-section, it is likely that the TDC assessment is more sensitive to the immediate effects of MLD treatment. The substantial percentage change in TDC as a reflection of local tissue water, but much smaller change in girth, are consistent with this and suggest that TDC measurements may be useful as complementary or perhaps an independent assessment method of edema/lymphedema and treatment-related changes.

This approach to characterizing edema and its change, as compared with other methods such as limb girth, limb volumes, bioimpedance and others (1,3,9-11,14,16, 25-27), has advantages and disadvantages. Its simplicity of use and rapidity of data acquisition are clearly positive features; a single measurement takes about 10 seconds. In view of its ability to measure locally and the fact that different tissue depths can be investigated with different size probes, new possibilities in basic research become available (17,28). One major clinical advantage is its ability to assess local areas such as those associated with localized limb edema or areas for which intensive therapy is being focused. Perhaps its greatest advantage is the fact that assessments can be made in any body area or part since the measurement method is not limited to limbs as are most other methods. Thus it should be possible to assess edema/lymphedema and their change in the hand, finger, head, neck, genitalia, and thorax and so on. Assessments of these possibilities need to be investigated and validated with further research. Potential functional disadvantages derive from the fact that TDC measurements are indicators of local conditions that may or may not be indicators of average or overall changes. When measurements are confined to the limbs, the use of combined methods may overcome this potential limitation if needed. For other body parts there is no other effective method known to the authors. Finally, a potential limitation for some centers may be the cost of the device. A single probe system, which is fully adequate for clinical assessments is currently about $11,500. This cost is an important consideration, and each center will need to contemplate the potential advantages of this method with respect to its cost.

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