Skin Water in Persons with Diabetes Mellitus (DM) Assessed by Tissue Dielectric Constant (TDC) Measured at 300 MHz

Bansari Sarkar OMS- III, Irina Volosko OMS- III, Naushira Pandya MD and Harvey N Mayrovitz PhD
Colleges of Osteopathic Medicine and Medical Sciences, Nova Southeastern University

Background

Worldwide, there are about 285 million people with Diabetes Mellitus (DM) and about 1/3 of them have skin related changes[1-4]. Prior research showed alterations in skin-to-fat tissue water especially prevalent in foot dorsum skin[5] but specific mechanisms have not been clarified. Literature is consistent with the theory that hyperglycemia-induced non-enzymatic glycation of structural and regulatory proteins may play a role in the pathogenesis of diabetic complications. In this scenario, excess supply of glucose in the blood plasma leads to a non-enzymatic chemical reaction between the carbonyl group of glucose and the amino acid of proteins[6]. This glycation of structural and regulatory proteins might play a role in the pathogenesis of diabetic skin complications[7].

Objectives

Our purpose was to test the hypothesis that in persons with DM the dermal collagen glycation displaces bound water and thereby decreases skin tissue water. If true then a measurable inverse relationship between skin water and HbA1c should be present. Hence, we tested for a positive relationship between skin-to-fat tissue water measured by Tissue dielectric constant (TDC) and HbA1c values in persons with DM. If a correlation was present it might be used to implement preventative care in patients with DM with a specific range of HbA1c values. Because there are differences in TDC values between genders measurements were done on both male and female subjects[8].

Subjects

A total of 41 persons (28 female) participated in this study after signing an IRB approved consent form. The data were collected after the scheduled appointment time of the patient at clinic. There were 36 Type II DM patients and 5 Type I DM patients included in the study. Other subject data is in Table 1.

Measurements and Protocol

TDC MEASUREMENTS were done using the MoistureMeter-D, (Fig 1). The MMD is a non-invasive, battery operated hand-held device utilizing gold plated brass open-ended coaxial probes (Fig 3a, b). The probe measures TDC at 300 MHz. For this study probes used had an effective penetration depths of 0.5, 1.5, 2.5 and 5.0 mm. Three sites were measured on one body side; (1) anterior forearm 6 cm distal to the antecubital fossa, (2) gaiter area 10 cm superior to the medial malleolus and (3) foot dorsum between the junction of the 1st and 2nd toes. Each site was measured in triplicate and averaged.

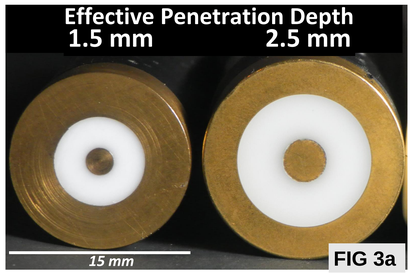
BIOIMPEDANCE MEASUREMENTS were done to obtain total body composition using the Ironman InnerScan Body Composition Monitor (Figs 2 & 3c). It is a non-invasive, battery operated device that measures electrical impedance while the subject stands. The subject's gender, birth date, and height are entered into the device after which the subject steps onto the scale and grips two attached handles for a period of about 20 seconds. Measured parameters include: weight, %body fat, %body water, muscle mass, and limb segmental values.

Measurement Methods

FIG 1. TDC Measurements
Tissue Dielectric Constant is the ratio of the tissue permittivity to that of a vacuum. Here it is measured at 300 MHz and is directly related to free and bound H_2O content in the measuring volume. The device is the Moisture Meter-D made by Delfin Technologies, Kuopio Finland. A probe contacts skin for less than 10 sec for a reading. TDC was measured to effective depths of 0.5, 1.5, 2.5 and 5.0 mm. For reference, the dielectric constant of H_2O is 76 at 34°C.

FIG 2. Body Composition
Bioimpedance was used to estimate total body & segmental composition parameters including total body $\%H_2O$ & %Fat and muscle mass (MM) & arm & leg %Fat & MM. The method uses small electrical current (50KHz) , to determine impedance and then uses a model representation of the body components.

Algorithms to estimate body parameters from the model are usually company private.

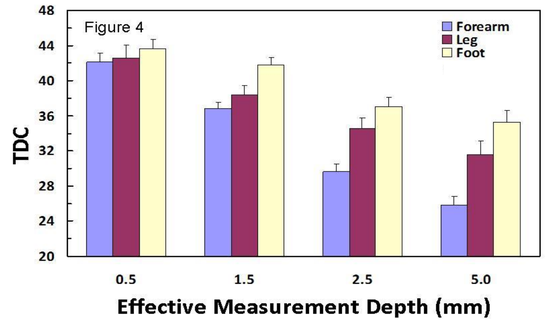


Subject Descriptive Parameters

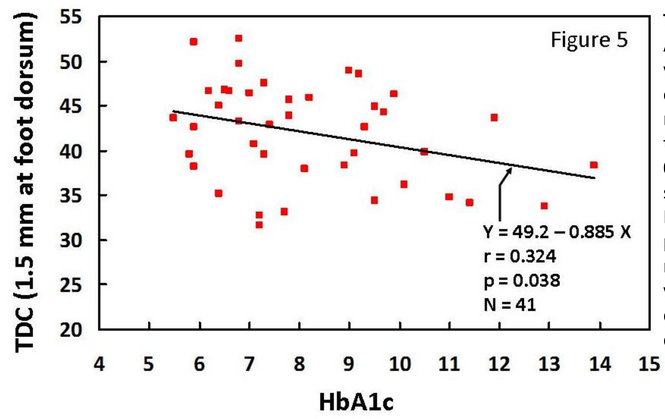
TABLE 1

	range	mean ± standard deviation
Age (yr)	31-86	65.9 ± 14.7
BMI (kg/m^2)	19.1-36.6	27.1± 5.1
HbA1c (check)	5.5-12.9	8.1± 1.8
Glucose (mmol/L)	92-349	171.3 ± 61.7
Total Body Water (%)	40.6-60.4	48.6 ± 5.4
Total Body Fat (%)	15.6-43.8	32.4 ± 7.5
BP Systolic (mmHg)	98-180	121.2 ± 20
BP Diastolic (mmHg)	50-100	72 ± 11.9

Results



TDC VALUES BY SITE AND DEPTH
TDC values monotonically decreased with increasing measurement depth at all sites (forearm, leg and foot) with TDC values at 0.5, 1.5, 2.5 and 5.0 mm depths being significantly different from each other ($p<0.001$). At all depths except 0.5 mm there were significant differences in TDC values among sites ($p<0.001$) with TDC values of foot greater than leg and leg greater than forearm.



TDC – HbA1C CORRELATIONS
Analyses also showed that TDC values were significantly negatively correlated with HbA1c only as measured on the foot dorsum and then only at a 1.5 mm depth ($r = -0.332$, $p=0.034$). There was also a small positive correlation between HbA1c and % Arm fat ($r = 0.331$, $p=0.048$). However no significant negative correlation between TDC values and HbA1c was found at any depth or site except for the foot dorsum as shown in FIG 5.

Conclusions

The focus of this study was to test the hypothesis that HbA1c and skin-to-fat tissue water were related as measured at different depths and different sites of persons with DM. A trend for a negative correlation between TDC values and HbA1c was statistically significant only for foot dorsum for a measurement depth of 1.5 mm. This finding suggests that only about 12% of TDC variation could be explained by HbA1c variation. However, this dependence is unlikely to be of major clinical importance and may be related to a similarly found negative foot TDC-HbA1c correlation ($p<0.05$) with total body fat. Despite the absence of the hypothesized correlation the TDC depth and site data provide here provide hither-to-fore unavailable baseline information on patients with diabetes.

References

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