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In vivo Study of Skin Mechanical Properties in Scleredema of Buschke

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A non-invasive, in vivo suction device was used to investigate the mechanical properties of the skin in a patient with scleredema of Buschke. Clinical scoring of skin induration and measurements of skin elasticity were performed over 9 anatomic regions on admission and after 3 (on discharge), 17 and 28 months. Immediate distension, final distension and immediate retraction were significantly decreased, while the viscoelastic to elastic ratio was significantly increased in the patient as compared to the healthy controls. Delayed distension and biological elasticity were preserved. Low values of skin distensibility correlated with a severe skin induration ($p<0.001$). The changes were more expressive with the 8 mm-diameter measuring probe than the 2 mm-diameter probe. The method applied can be used for objective and quantitative assessment of skin involvement in scleredema of Buschke.

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Scleredema of Buschke (SB) is characterized by diffuse induration of the skin, due to the increased deposition of collagen and glycosaminoglycans in the dermis. The degree and extent of the skin involvement are usually rated subjectively according to a "skin score" obtained by clinical palpation. Thickening of the skin alters its mechanical properties. Therefore, measurements of the viscoelasticity can be used to quantify the hardness of the skin. Previous studies have demonstrated the advantage of some non-invasive techniques in the assessment of skin stiffness in scleroderma, morphea, psoriasis and lymphedema of the lower legs (1–7).

The aim of the present study was to investigate, by means of a non-invasive in vivo suction device, the mechanical properties of the skin and their relationship with the skin score as well as the therapeutic response and disease evolution in a patient with SB.

MATERIAL AND METHODS

Case report

A 54-year-old man was admitted to our clinic in December 1994 because of a non-pitting skin induration involving his face, neck, shoulders, arms, back and chest about 3 weeks after a sore throat. There was some limitation of facial expression and neck and shoulder mobility. Laboratory studies showed a normal full blood count, ESR, renal and liver function, chest and esophago-gastroduodenal roentgenograms. Antistreptolysin-O titer was raised (1 : 600 U). Before the therapy, blood glucose was 11.6 mmol/l and a newly type II diabetes was established. Electrocardiography showed a sinus bradycardia and left anterior hemiblock. Histology of a skin biopsy from the right shoulder (H&E) revealed a thickened dermis with swollen collagen bundles separated by clear spaces. The epidermis was normal.

Therapy was started with penicillin, 6 million U/day reduced to 2 million U/day intramuscularly for 5 weeks, methylprednisolone, 80 mg/day reduced to 8 mg/day intramuscularly for 8 weeks, glibenclamidum 2 mg/day and triamterene, 50 mg/day orally, as well as physiotherapy with madecassol ointment. Indomethacin, 100 mg/day for a month rectally, and azathioprine, 150 mg/day orally for 2 weeks, were administered later. After discharge the patient refused to receive any therapy. His general health was unchanged.

Controls

Ten healthy subjects (5 male, 5 female, mean age 51, range 45 to 55 years) were studied. They were comparable with the patient in regard of sunlight exposure.

Skin elasticity measurements

Mechanical properties of the skin were measured with a non-invasive, in vivo suction skin elasticity meter (Cutometer® SEM 474, Courage and Khazaka, Köln, Germany). The time/strain mode was used with a 5-s application of a vacuum of 400 mbar, followed by a 5-s relaxation period. A typical skin deformation curve is illustrated in Fig. 1. The parameters used were immediate distension (Ue), delayed distension (Uv), final distension (Uf) and immediate retraction (Ur). All the parameters are a function of skin thickness and thus cannot be simply compared between regions and subjects. Because data on skin thickness were not available we analysed the ratios of these parameters, too. Uv/Ue, the ratio of delayed deformation to immediate deformation, and Ur/Uf, the ratio of immediate retraction to total deformation, called biological elasticity, have been reported to be independent of skin thickness and can be compared between sites and subjects (8–10). Two measuring probes with different apertures were used. The small 2-mm diameter probe determines the mechanical properties of the epidermis and papillary dermis, while the large 8-mm diameter probe determines those of the whole skin (8).

Skin score

Severity of the cutaneous induration was rated according to a 4-point scale (0: normal skin, 1: mild, 2: moderate and 3: severe skin induration).

Study design

Clinical assessment and measurements of skin elasticity were performed on admission and after 3 (on discharge), 17 and 28 months

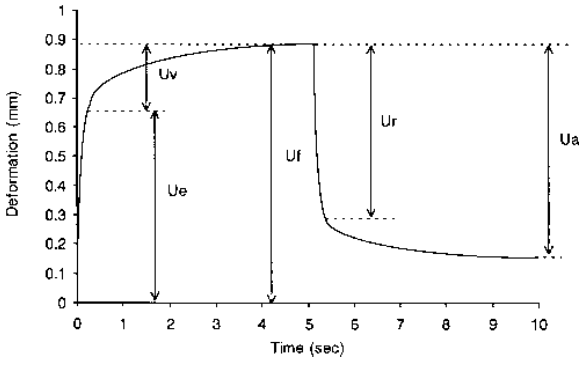

Fig. 1. Skin deformation curve obtained with Cutometer.

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over 9 anatomic regions: forehead (center), cheeks, infraclavicular regions, upper arms (outer middle third) and volar forearms (center). The patient's site values were compared with the 95% confidence intervals by site of the controls. In addition, the average values calculated were compared with those of the healthy subjects.

Statistical analysis

The Wilcoxon signed rank test was used to analyse the clinical scoring. The Student's *t*-test for paired and unpaired data was used to compare the mean values of the mechanical parameters. The relationship between the skin score and Cutometer measurements was studied using the Spearman rank correlation test. Correlation between the skin mechanical parameters was studied using the Pearson correlation test. A level of $p<0.05$ was considered significant.

RESULTS

Response of SB

Clinical assessment of the patient during the study revealed skin severity scores between 1 and 3 (Table I). On admission the mean skin score was 1.66. At 3 months (on discharge) the mean score had increased to 2.66 ($p<0.01$). Seventeen and 28 months later the mean values were decreased to 2.11 and 1.44 ($p<0.01$), respectively. There was no significant difference between the initial and the final skin score. Upper arms and forearms were most affected. Normal control subjects were given a score of 0 induration for all 9 anatomic regions.

Skin elasticity measurements

Comparison with the 95% confidence intervals by site of the controls. All over the anatomic regions, the patients values of the parameters Ue, Uv, Uf (Table I) and Ur were below the corresponding confidence intervals of the controls, except for the initial values measured on the patients cheeks. Values of the ratios Uv/Ue and Ur/Uf (8-mm probe) were above the confidence intervals of the controls. The changes observed were more expressive on the upper arms and volar forearms, as well as at months 3 and 17.

Comparison of the average values calculated. Results are presented in Fig. 2. Initial skin elasticity measurements revealed lower parameters Ue ($p<0.05$, 2-mm probe; $p<0.001$, 8-mm probe), Uf ($p<0.01$, 8-mm probe) and Ur in the patient compared with the healthy controls. Uv was unaltered but the ratio Uv/Ue was raised significantly ($p<0.05$, 2-mm probe; $p<0.001$, 8-mm probe). Biological elasticity Ur/Uf was preserved (2-mm probe) and even increased ($p<0.001$, 8-mm probe).

At 3 months (on discharge) a decrease of the absolute parameters Ue ($p<0.05$), Uv ($p<0.001$), Uf ($p<0.01$), Ur ($p<0.05$, 2-mm; $p<0.001$, 8-mm probe) was observed, but there were no significant changes in biological elasticity Ur/Uf or viscoelastic parameter Uv/Ue.

At months 17 and 28 there was a tendency to normalisation but the parameters Ue, Uf, Uv/Ue and Ur/Uf (8-mm probe) continued to be significantly different from those of the healthy subjects.

Correlation between skin mechanical parameters. Using both probes, a significant direct relationship ($p<0.001$) was established between the parameters Ue, Uv, Uf and Ur as well as between Ur/Uf and the parameters Ur and Uv/Ue ($p<0.05$). An inverse correlation ($p<0.001$) was found between Uv/Ue and the parameters Ue, Uf, Ur (8-mm probe).

Correlation between clinical score and skin mechanical parameters. An inverse relationship ($p<0.001$) was found between the skin severity score and the parameters Ue, Uv, Uf and Ur. Fig. 3 shows the correlation of final skin distension (Uf) with the clinical score. Low values of extensibility correlated with severe skin induration. All differences between the values were statistically significant, except for those between the scores 1 and 2 (2-mm probe). With the 8-mm diameter probe a significant direct correlation ($p<0.001$) was found between the skin severity score and the parameters Uv/Ue and Ur/Uf.

DISCUSSION

In the present study we used for the first time a suction skin elasticity meter to evaluate the mechanical properties of the skin in a patient with SB.

All the parameters investigated are related to corresponding changes of the skin structure and composition (8–10). Ue and Uf are linked to the stretching of collagen and elastic fibers and reflect skin thickness and rigidity. Uv and Uv/Ue represent the viscoelastic part of the deformation and are attributed to the displacement of the interstitial fluid (containing highly viscous glycosaminoglycans) throughout the fibrous network. Ur and Ur/Uf measure the ability of the skin to return to its initial position after deformation and are related to the function of the elastic fibers. The ratios of absolute parameters have been reported to be independent of skin thickness and thus can be compared between sites, subjects and time points (8–10).

The decreased parameters Ue, Uf and Ur in SB indicated an increased hardness of the skin. This is due to the thickening of the collagen bundles and enlarged volume of the subcutaneous tissues, as the result of a deposition of mucopolysaccharides in the dermis and its modified hydration. The collagen and elastic fibers are already stretched in rest and skin extensibility is decreased. Generalized scleroderma and the progressive lesions of morphea are also characterized by reduced skin distensibility (1, 2, 5). However, this is due to the dense accumulation of collagen and thus interpretation is different in these diseases.

Uv is inversely proportionate to the coefficient of viscosity of ground substance (7). The increased amounts of proteoglycans (chiefly hyaluronic acid) in the dermis normally lead to increased viscosity. Initial Uv values in our patient were unaltered substantially but considerably reduced at 3 months. The viscoelastic to elastic ratio Uv/Ue was raised at the expense of the severely reduced elastic distension of the skin.

Biological elasticity Ur/Uf was preserved and even relatively increased (8-mm probe). This suggests that elastic tissue is not involved in the pathological process. Moreover, the collagen bundles in scleredema are separated from each other by spaces filled with variable amounts of mucin, which diminishes the friction between fibers in the reticular dermis and facilitates the movement of interstitial fluid.

Clinical assessment and the skin elasticity changes at 3 months indicated a lack of any clinical improvement and even a disease aggravation despite the treatment applied. Results obtained at months 17 and 28 showed a normalization of all parameters investigated, although they still remained different

Table I. *Clinical score and final distension of the skin at different anatomic regions*

Region	1 month			3 months			17 months			28 months			Controls ($n=10$)				
	S	Uf		S	Uf		S	Uf		S	Uf		S	2 mm probe		8 mm probe	
		2 mm	8 mm		2 mm	8 mm		2 mm	8 mm		2 mm	8 mm		Uf	95% CI	Uf	95% CI
Forehead	1	0.21	0.74	2	0.18	0.47	1	0.25	0.7	1	0.25	0.79	0	0.271	0.219–0.323	0.963	0.867–1.059
Cheek																	
right	1	0.37	1.06	2	0.21	0.58	2	0.2	0.66	1	0.22	0.71	0	0.259	0.215–0.303	0.853	0.722–0.984
left	1	0.3	1.06	2	0.14	0.52	2	0.21	0.56	1	0.22	0.73	0	0.26	0.225–0.295	0.844	0.691–0.997
Infra-clavicular																	
right	2	0.33	0.48	3	0.19	0.46	2	0.29	0.94	2	0.3	0.82	0	0.371	0.328–0.414	1.034	0.965–1.103
left	2	0.34	0.55	3	0.21	0.47	2	0.3	0.89	2	0.3	0.83	0	0.393	0.351–0.435	1.126	1.003–1.249
Upper arm																	
right	2	0.14	0.47	3	0.08	0.22	3	0.21	0.52	2	0.19	0.74	0	0.309	0.287–0.331	1.076	0.981–1.171
left	2	0.12	0.55	3	0.09	0.33	3	0.18	0.48	2	0.23	0.69	0	0.317	0.290–0.344	1.099	0.983–1.215
Volar forearm																	
right	2	0.24	0.56	3	0.19	0.34	2	0.16	0.66	1	0.21	0.81	0	0.332	0.301–0.363	1.03	0.939–1.121
left	2	0.27	0.69	3	0.21	0.54	2	0.2	0.77	1	0.2	0.86	0	0.351	0.331–0.371	1.036	0.961–1.111
Mean	1.66	0.258	0.684	2.66	0.167	0.437	2.11	0.222	0.687	1.44	0.236	0.776	0	0.318	0.286–0.350	1.007	0.941–1.073
SD	0.5	0.088	0.23	0.5	0.051	0.117	0.6	0.048	0.158	0.53	0.04	0.06		0.049		0.101	

S = score; Uf = final distension, mm; 95% CI = 95% confidence interval, mm; SD = standard deviation; 2 mm = 2 mm probe; 8 mm = 8 mm probe.

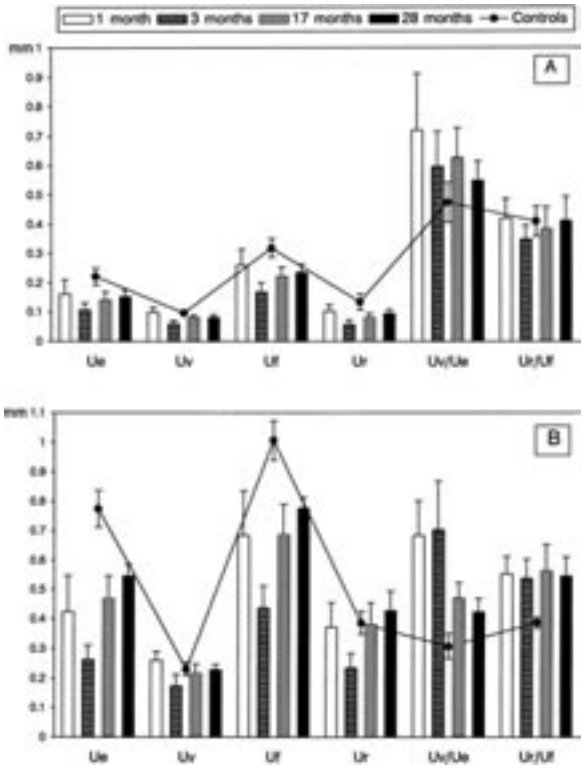

Fig. 2. Skin mechanical parameters in scleredema of Buschke and controls measured by a 2 mm-diameter probe (A) and an 8 mm-diameter probe (B). The average values and 95% confidence intervals are shown.

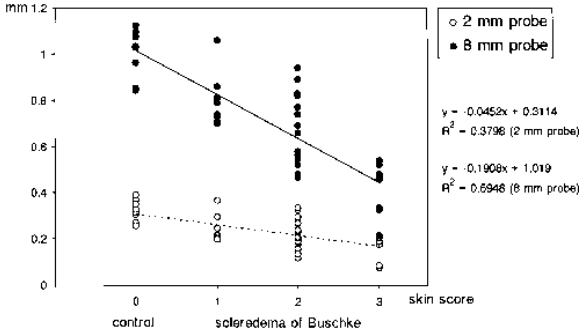

Fig. 3. Correlation of final distension (Uf) with clinical skin score.

from those of the healthy subjects. This supports that SB is not always responsive to therapy and is a self-limited disease with a chronic course that may resolve spontaneously (11, 12).

The cutometer measurements correlate with the clinical skin score and are very suitable for intraindividual comparisons during follow-up. Because of the direct relationship between all absolute parameters established, we give priority to the total skin distensibility Uf in the assessment of SB. If Uf cannot be standardized for skin thickness, the viscoelastic ratio Uv/Ue can be used in addition. This parameter inversely correlates with Ue and Uf. Thus, the increase in skin distensibility and the decrease in Uv/Ue indicate a reduction of skin thickness, i.e. an improvement of the disease.

The pathological process of scleredema involves the dermis and subcutaneous tissues. Therefore, the large 8-mm diameter measuring probe, which determines the viscoelastic properties of the whole skin, is more suitable than the small 2-mm diameter probe. Our data are in accordance with the results reported by Enomoto et al. (1) in patients with generalized scleroderma.

The present study confirms that the non-invasive, in vivo suction method applied can be useful in the quantification of skin involvement and disease progression in patients with SB.

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