Quantification of Acrosclerosis: Measurement of Skin Thickness and Skin–phalanx Distance in Females with 15 MHz Pulsed Ultrasound

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The skin thickness of the extensor and flexor aspects of the forearm (TEF, TFF), and the skin–phalanx distance over the middle and proximal phalanges (DMP, DPP) were measured with a 15 MHz ultrasound (A-scan) apparatus. Twenty-two females with systemic sclerosis (acrosclerotic type) and 22 healthy females matched for age were studied. DMP, DPP, TEF and TFF measurements were all increased in systemic sclerosis ($p<0.001$, $p<0.001$, $p<0.01$, $p<0.02$). Standards for normal skin–phalanx distance and skin thickness in females were defined (mean ± 2 SD). DMP and DPP were not correlated to age in the controls. TEF and FEF decreased slightly with age, 0.078 and 0.062 mm/10 years of life respectively. DMP was increased in 18 (82 %), DPP in 13 (59 %), TEF in 7 (32 %) and TFF in 5 (23 %) patients with systemic sclerosis, as compared with standards defined. Non-invasive measurement of skin–phalanx distance of the digits and skin thickness of the forearm with high-frequency ultrasound is concluded to be proper for the diagnosis of acrosclerosis and for quantification of sclerodermatous skin changes during medical treatment. (Received February 22, 1983.)

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Skin thickness was previously determined by histological sections, skin-fold recordings, or by xeroradiography. In 1979 Alexander & Miller presented a high-frequency ultrasound technique for non-invasive measurement of skin thickness (1). In 1981 Tan et al. presented an ultrasound biometric ruler, used to measure dermal thinning during treatment with local steroids (7, 8). Both centres found a high degree of correlation with the xeroradiographic method.

In 1980–81 we have developed a high-frequency ultrasound apparatus with dimensions and other improvements which made possible the measuring of digits. In an initial study with this apparatus we showed that echoes could be obtained from the dermis/subcutaneous tissue junction in localized scleroderma plaques as well as in normal skin (6). The sclerotic plaques were 1.5–2 times as thick as regional control measurements of normal-appearing skin.

Objective and non-invasive methods are needed for quantification of the skin changes in systemic sclerosis. In the present study we measured the skin thickness of the forearm, and the soft tissue thickness of the digits in females with systemic sclerosis, and healthy females matched for age.

MATERIAL AND METHODS

The ultrasound A-scan apparatus employed was constructed after the main principles of Alexander & Miller (1). An unfocused transducer with a resonant frequency of 15 MHz was used (Figs. 1 and 2).
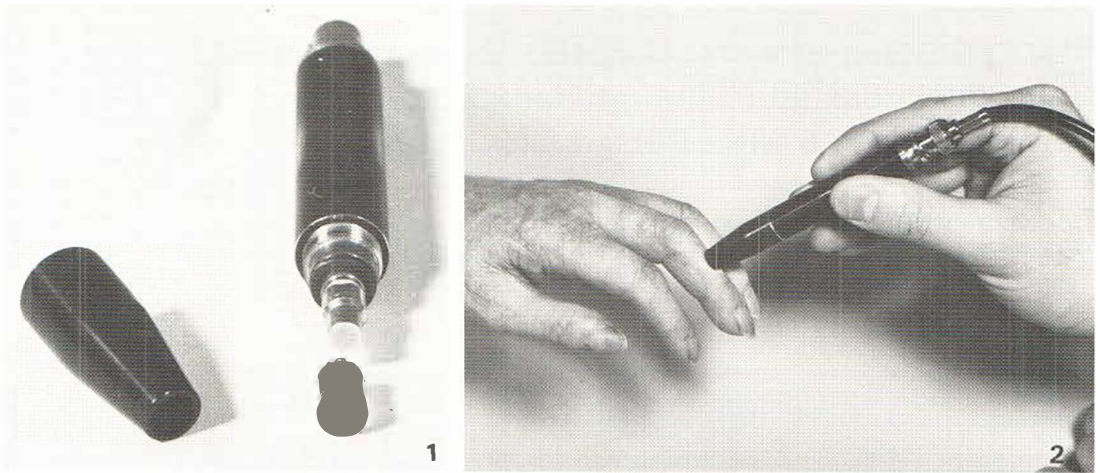
Fig. 1. High frequency transducer, 5 mm in diameter, with a hardened gelatin plug instead of water bath.

Fig. 2. Measurement of skin–phalanx distance over the middle phalanx.

The diameter of the transducer was only 5 mm, permitting the measurement of digits. Instead of a water bath, a gelatin plug hardened with glutardialdehyde was prepared to avoid problems with air bubles and water running out of the system. A vacuum was not needed to obtain echoes from the dermis/subcutaneous tissue junction. The pulse transit time and reflected signal amplitude were displayed on a cathode ray tube with electronic indicator of distance adjusted for skin measurements. The tube images were photographed with a Polaroid® camera. For calculation of skin and soft tissue thickness, an acoustic velocity of 1518 m/sec was used (5). Measurements can be reproduced with 0.1 mm precision (6). An example of measurements performed with our apparatus is shown in Fig. 3.

The patient material consisted of 22 females with systemic sclerosis of the acrosclerotic type. Their mean age was 61 years (range 32–83). They all met the diagnostic criteria of The American Rheumatism Association (2). Their mean duration of systemic sclerosis was 11 years (range 1½–25). Twenty-one patients received medical treatment with inhibitors of collagen synthesis, as described by Asboe-Hansen (2, 3). Fifteen received penicillamine, 21 glutamine and 2 hydralazine, while 1 patient was
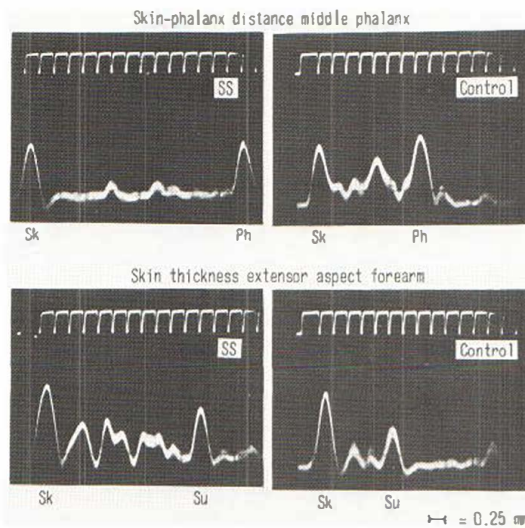

Fig. 3. Examples of ultrasound measurements in a patient with systemic sclerosis (SS), and a healthy control. Sk = skin surface, Ph = phalangeal shaft, Su = dermis-/subcutaneous tissue junction.
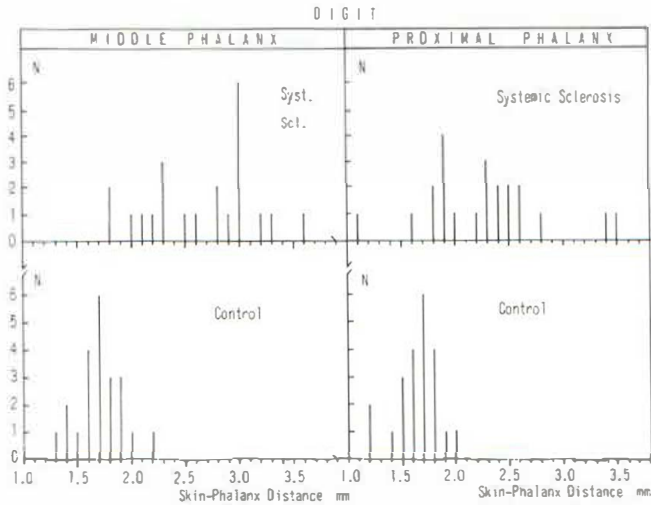
Fig. 4. Skin–phalanx distance over the third digit of the right hand of 22 females with systemic sclerosis, and 22 healthy females matched for age. Mean values and SD, see Table 1.

untreated. The treatment had been given for a mean period of 3 years (range ½–6). Twenty-two healthy females matched with respect to age were studied for control pruposes. Their mean age was 58 years (range 29–87).

All measurements were performed consecutively. The skin–phalanx distances were measured over the extensor aspects of the middle phalanx and the proximal phalanx of the third finger of the right hand. The skin thickness was measured on the extensor and flexor aspects of the distal forearm. The skin thickness of the digits and hands is anatomically poorly defined because of a great number of subcutaneous retinacula, a sparse amount of subcutaneous adipose tissue, and the presence of gliding tissue instead of subcutaneous adipose tissue in some locations. Therefore, neither with ultrasound techniques nor with xeroradiography is it possible to measure the thickness of the skin of digits. However, in this study ultrasound echoes could easily be obtained from the extensor surface of the phalangeal shafts and, in this way, the soft tissue thickness of the digits could easily be measured.

The statistical analysis was performed by the χ^2-test with Yates correction. The relation between distances measured and age of the controls was analysed by linear regression. Standards of normal distances and thickness were defined in the control group as mean values ± 2 SD.
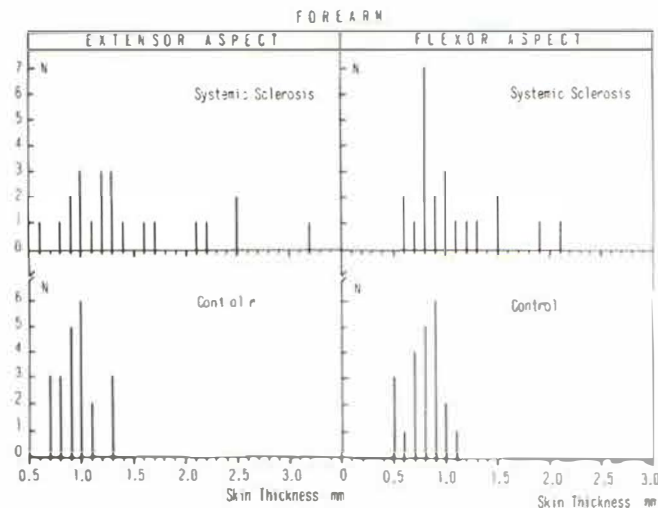

Fig. 5. Skin thickness of the right forearm of 22 females with systemic sclerosis and 22 healthy females matched for age. Mean values and SD, see Table 1.

Table I. *Ultrasound measurements in 22 females with systemic sclerosis and 22 healthy females matched for age with definitions of standards of normal skin–phalanx distance and skin thickness of the forearm of elderly females (mean ± 2 SD)*

	Systemic sclerosis Mean (range)	Control Mean (range)	SD	Mean ± 2 SD
Third digit, skin–phalanx distance, mm				
Middle phalanx	2.7 (1.8–3.6)	1.7 (1.3–2.2)	0.21	1.3–2.1
Proximal phalanx	2.3 (1.1–3.5)	1.6 (1.2–2.0)	0.20	1.2–2.0
Forearm, skin thickness, mm				
Extensor aspect	1.5 (0.6–3.2)	1.0 (0.7–1.3)	0.18	0.6–1.4
Flexor aspect	1.0 (0.6–2.1)	0.8 (0.5–1.1)	0.17	0.4–1.2

RESULTS

The skin–phalanx distances of the extensor aspect of the middle and proximal phalanges were increased ($p<0.001$, $p<0.001$) in females with systemic sclerosis as compared with the controls (Fig. 4).

The skin thickness of the extensor and flexor aspects of the forearm were also increased ($p<0.01$, $p<0.02$), though less significantly (Fig. 5).

The mean values, ranges, standard deviations, and the defined standards of normal thickness and distances in females from the control material are shown in Table I. The number of patients and control persons with increased and decreased values according to the defined standards are shown in Table II. Eighteen patients (82%) had increased skin–phalanx distance over the middle phalanx, 13 (59%) had increased skin–phalanx distance over the proximal phalanx, 7 (32%) had increased skin thickness of the extensor aspect of the forearm, and 5 patients (23%) had increased skin thickness of the flexor aspect of the forearm. In the entire material there might be a tendency to increasing skin–phalanx distances and skin thickness during the first year of treatment, with a peak

Table II. *Ultrasound measurements in 22 females with systemic sclerosis and 22 healthy females matched for age*

Number of persons with increased, 'normal' (in defined range), and reduced values, according to defined standards

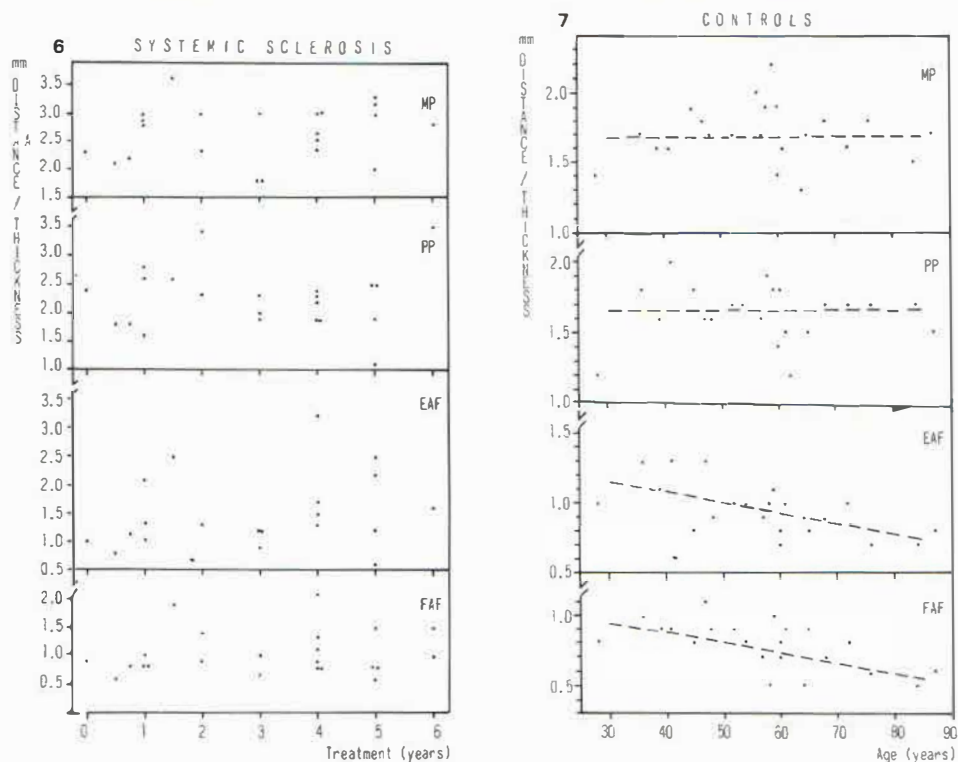|	Systemic sclerosis, n			Control, n		
	In-creased	'Normal'	De-creased	In-creased	'Normal'	De-creased
Third digit, skin–phalanx distance, mm						
Middle phalanx	18	4	0	1	21	0
Proximal phalanx	13	8	1	0	22	0
Forearm, skin thickness						
Extensor aspect	7	15	0	0	22	0
Flexor aspect	5	17	0	0	22	0

Fig. 6. Systemic sclerosis: Relation between ultrasound measurements (skin–phalanx distance of digit, skin thickness of forearm), and years of medical treatment in 22 females. MP = middle phalanx, PP = proximal phalanx. EAF = extensor aspect of forearm, FAF = flexor aspect of forearm.

Fig. 7. Control females: Relation between ultrasound measurements (skin–phalanx distance of digit, skin thickness of forearm), and age of 22 healthy females. MP = middle phalanx, PP = proximal phalanx, EAF = extensor aspect of forearm, FAF = flexor aspect of forearm.

after 1–2 years of treatment, followed by decreasing values and a plateau in the majority of cases after 3 and more years of treatment with a collagen biosynthesis inhibitor (Fig. 6).

In the control group there was no linearity between skin–phalanx distances over the middle and proximal phalanges, and age (correlation coefficients 0.024 and −0.025), and the curves showed no particular tendency (Fig. 7). There was a linear correlation of moderate strength between the skin thickness of the forearm, extensor and flexor aspects, and age, with correlation coefficients of −0.634 and −0.557. The skin thickness of the extensor and flexor aspects of the forearm decreased 0.078 and 0.062 mm per 10 years of life.

DISCUSSION

The patient material of this study was heterogeneous because of differences in the duration of systemic sclerosis, the medical treatment and the duration of the treatment.

In the early phase of systemic sclerosis, at the time of diagnosis, sclerodactyly and proximal scleroderma were found in 96% and 91% of patients with a definite diagnosis in the American Rheumatism Association study (2). It had been shown by Asboe-Hansen that with the medical treatment with inhibitors of connective tissue formation used in this

department, the skin changes in systemic sclerosis, assessed clinically, regressed in 73.9% of patients, and the progression arrested in a total of 88.7% (3, 4).

Despite the heterogeneity of the material we found that 82% of patients had incresed skin–phalanx distance over the middle phalanx. The results indicate that measurement of skin–phalanx distance is helpful for the diagnosis of acrosclerosis even after treatment has been started. The skin–phalanx distance over the proximal phalanx was a less sensitive parameter, i.e. increased in 59% of patients. Measurement of skin–phalanx distance as a whole as an expression of soft tissue thickness is relevant, considering the histopathology of scleroderma in which the subcutaneous tissue becomes organized, fibrotic and thickened during progression. The skin–phalanx distance was not correlated to age in healthy controls, and it is therefore not necessary to subdivide the standards defined in age groups.

In the extensor and flexor aspects of the forearm, 32% and 23% of the patients had increased skin thickness. This corresponds well to the frequent finding of proximal scleroderma at the time of diagnosis, as reported by The American Rheumatism Association, and the large number of patients with regression clinically during treatment reported by Asboe-Hansen (2, 3, 4). The results may indicate, as compared with the digits, that the sclerodermatous skin changes regress more frequently on proximal parts of the extremities. This is in agreement with the well known acral distribution of systemic sclerosis. The results indicate that measurement of skin thickness of the forearm is an important parameter for quantification of the effect of medical treatment regimens in systemic sclerosis. The skin thickness probably needs be measured repeatedly for a minimum of 3 years in order to record any possible effect of medical treatment (Fig. 6). Measurements in the control group showed a slight decrease with age in skin thickness of the forearm. This decrease was minute, however, as compared with the increase of 1.5–2 times in thickness in skin affected by scleroderma.

The skin thickness of the forearm of the control females was identical with the values reported by the Cardiff group (7). This demonstrated the precision and the objectivity of the ultrasound method for measuring thickness of the skin.

Sex differences in skin thickness certainly exist. Studies in males are in progress.

ACKNOWLEDGEMENTS

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