Localized Scleroderma (Morphoea): Thickness of Sclerotic Plaques as Measured by 15 MHz Pulsed Ultrasound

JØRGEN SERUP

University of Copenhagen, Department of Dermatology, Rigshospital, Copenhagen, Denmark

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The thickness of morphoea plaques was measured by A-mode ultrasound and compared to regional control measurements in the same individuals. The thickness of morphoea plaques was increased by 18–310% in 17 patients with one or a few morphoea plaques ($p<0.01$), and by 13–145% in 6 patients with generalized morphoea ($p<0.05$). The increase in thickness of morphoea plaques was local confined to the plaques. Ipsilateral and contralateral control measurements were not different, and measurements in a standard region (forearm) were not different from those in a group of healthy controls matched for sex and age. Plaques of clinically 'advanced' scleroderma were more thickened ($p<0.01$) than plaques of 'slight' scleroderma. The relative increase in thickness was larger ($p<0.01$) in skin with a habitual thickness of 0.8–1.1 mm. The habitual skin thickness on the extremities (mean 1.0 mm) was less ($p<0.01$) than on the trunk (mean 1.5 mm), and, consistently, plaques with 'advanced' scleroderma were more frequent ($p<0.05$) on the extremities. Ultrasound measurement of skin thickness was accurate with SD form 0.05–0.09 mm and coefficients of variation from 3–7% in reproducibility studies of typical morphoea plaques as well as normal appearing skin. (Received July 11, 1983.)

J. Serup, Ingeborgvej 42, DK-2900 Hellerup, Denmark.

In 1980–81, we developed a 15 MHz A-mode ultrasound apparatus for measurement of the skin thickness. Quantitative studies of skin thickness in the acrosclerosis type of systemic sclerosis have already been reported (1). In this study intitial experiments in patients with localized scleroderma (morphoea) are reported.

MATERIAL

Twenty-three patients with a clinical and histological diagnosis of localized scleroderma (morphoea) were studied. Seventeen patients suffered from localized morphoea plaques (LMP), i.e. one or a few plaques in one or a few anatomical regions. Their mean age was 35.5 years (range 11–70), and the mean duration of morphoea was 1.9 years (range 1/4–8). Six patients suffered from generalized morphoea (GM), i.e. several plaques typically large in size located to different anatomical regions. Their mean age was 56.0 years (range 31–77), and the mean duration of morphoea was 2.2 years (range 1/6–8).

Only plaques with the classical clinical signs of scleroderma, i.e. white colour, induration and increased skin thickness on palpation were studied. One typical plaque in each patient was selected. The degree of scleroderma on clinical examination prior to measurements was 'advanced' in 14 patients with LMP and in one patient with GM, while 3 and 5 patients in the two groups presented 'slight' scleroderma.

In patients with LMP, 8 plaques were located to the trunk, 3 to the upper extremities, and 6 to the lower extremities. In patients with GM, 5 plaques were located to the trunk (including one on the neck), and one to an upper extremity.

Control studies

In 13 patients (10 LMP, 3 GM) contralateral regional control measurements of normal appearing skin were supplemented with ipsilateral measurements of normal appearing skin in the same region as the morphoea plaque to evaluate if contralateral and ipsilateral control measurements were comparable.

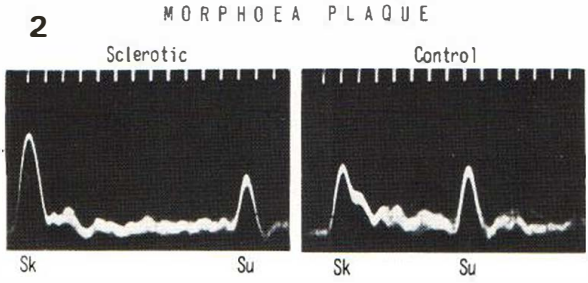

Fig. 2. Example of A-mode ultrasound measurement of skin thickness of a morphoea plaque. Sk=skin surface, Su=dermis/subcutaneous tissue interface.

Fig. 1. Probe with 15 MHz transducer for ultrasound measurement of skin thickness. Gelatine plug (middle) and conical headpiece (left). Devices for measurements under water bath (right). Cylindrical bath is fastened to skin surface by double adhesive tape.

In 10 patients (6 females, 4 males, 7 LMP, 3 GM) with a mean age of 40.1 years (range 11–59) the skin thickness of normal appearing skin of the extensor and flexor aspects of the forearm were measured and compared to 10 healthy subjects matched with respect to sex and age (6 females, 4 males, mean age 41.0 years, range 5–66 years).

METHOD

The skin thickness of the sclerotic centre of morphoea plaques was measured and compared to regional control measurements of normal appearing skin in the same individuals. In patients with LMP, 5 measurements were performed with ipsilateral control and 12 with contralateral control. In patients with GM, 4 measurements were performed with ipsilateral control and 2 with contralateral control.

The ultrasound A-mode apparatus was constructed after the main principles described by Alexander & Miller (2). An unfocused transducer with a resonant frequency of 15 MHz was used (Fig. 1). The diameter of the transducer was only 5 mm, and the external diameter of the probe 8 mm. Instead of a water bath, a gelatine plug hardened with glutardialdehyde and preserved with benzoic acid was prepared to avoid problems with air bubbles and water running out of the system. With this modification the position of the probe could easily be moved a little bit on the skin surface searching the better interface-echoe. A special vacuum system was not needed. In any case of doubt about the origin of profound echoes 5–10 ml atmospheric air was insufflated into the subcutaneous tissue giving powerful interface-echoes. The pulse transit time and reflected signal amplitude were displayed on a cathode ray tube with electronic indication of distance adjusted for skin measurements. The tube images were photograhed with a Polaroid® camera. For calculation of skin thickness an acoustic velocity of 1518 m/sec was used as described by Daly & Wheeler in a post mortem study of human skin (3). Their study also showed that the ultasound velocity in skin does not change after application of pressure. The ultrasound wave-length in skin at frequency 15 MHz and velocity 1518 m/sec is 0.10 mm. In vivo studies in pig and cattle have shown ultrasound velocities in animal skin ranging from 1503 to 1591 m/sec (4). Examples of measurements performed with our apparatus are shown in Fig. 2. Skin thickness could be read from the photographed tube image with an apoproximate accuracy of 0.05 mm.

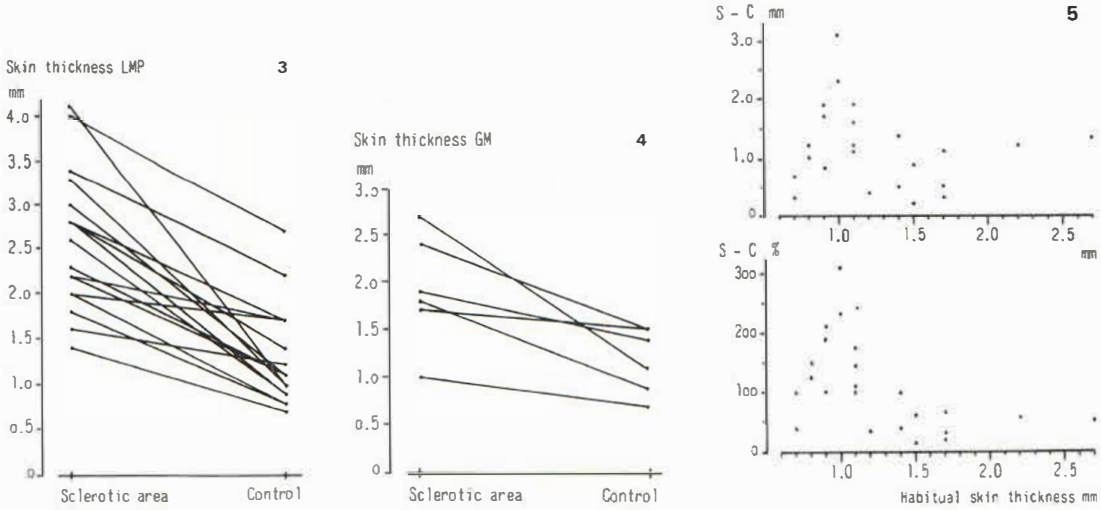

Fig. 3. Skin thickness of scleroderma plaques in patients with localized morphoea plaques (LMP).

Fig. 4. Skin thickness of scleroderma plaques in patients with generalized morphoea (GM).

Fig. 5. Absolute and relative increase in skin thickness (Sclerosis (S)–Control (C)) of morphoea plaques related to habitual skin thickness.

Reproducibility and variability studies

Twenty-four consecutive measurements from an abdominal morphoea plaque with 'slight' scleroderma were performed with gelatine plug and slight touch and from normal appering skin of the opposite side. Twenty-four consecutive measurements from a morphoea plaque with 'advanced' scleroderma located to one leg were performed in the same way with contralateral control. Ten consecutive measurements on a lower extremity of a healthy subject were performed under water bath followed by use of gelatine plug applied with slight touch. Eighteen measurements of an abdominal morphoea plaque and contralateral control region were performed with the gelatine plug and slight touch followed by 7 measurements with heavy pressure.

Statistical methods

Differences in skin thickness between morphoea plaques and their respective regional control measuremetns were analyzed by the Wilxocon signed rank test for paired observations. 'Advanced' and 'slight' degree of scleroderma versus location to trunk or extremity were analyzed by Fisher's exact test. Normal skin thickness of trunk versus extremities, and aboslute and relative differences in skin thickness between plaques with 'advanced' and 'slight' scleroderma, and between plaques located to the trunk and to the extremities were analyzed by the Wilcoxon rank sum test. Probabilities less than 0.05 were considered significant.

RESULTS

The results of skin thickness measurements in patients with LMP and GM appear from Table I, and in Figs. 3 and 4. The skin thickness of sclerotic area was increased in patients with LMP ($p<0.01$) as well as in patients with GM ($p<0.05$).

The increase in thickness of plaques of clinically 'advanced' scleroderma was larger ($p<0.01$) when compared to plaques of 'slight' scleroderma (Table II). Plaques located to the extremities tended to be more increased in thickness when compared to plaques located to the trunk (Table II). More plaques ($p<0.05$) of 'advanced' scleroderma were located to the extremities. Of 15 plaques of 'advanced' scleroderma, 9 were located to the extremities and 6 to the trunk. Only one plaque of 'slight' scleroderma was located to an extremity while 7 plaques were located to the trunk.

Table I. *Measurement of skin thickness of sclerotic plaques in patients with localized scleroderma*

S=sclerotic area, C=regional control

	Skin thickness (mm)			
	Sclerotic area	Regional control	Absolute difference S–C	Relative difference S–C (%)
Localized morphoea plaque, $n=17$				
Mean	2.6	1.3	1.3	120
Range	1.4–4.1	0.7–2.7	0.4–3.1	18–310
Generalized morphoea, $n=6$				
Mean	1.9	1.2	0.7	66
Range	1.0–2.7	0.9–1.5	0.2–1.6	13–145

The thickness of normal appearing skin of regional control areas was less ($p<0.01$) on the extremities (mean 1.0 mm, range 0.07–1.4) when compared to the trunk (mean 1.5 mm, range 0.7–2.7).

The absolute and relative increases in skin thickness of morphoea plaques related to habitual skin thickness of the individuals as indicated by regional control measurements are shown in Fig. 5. The absolute increase in thickness tended to be larger in skin with a habitual thickness of 0.9–1.1 mm, and the relative increase in thickness was statistically larger ($p<0.01$) in habitual thickness of 0.8–1.1 mm.

Control studies

The mean thickness of ipsilateral and contralateral control areas in 12 patients were 1.6 mm (range 0.8–2.8) and 1.6 mm (range 0.8–2.9), i.e. not statistically different. Numerical differences between the two sides were zero in 4 patients, 0.1 mm in 4 patients, and 0.2

Table II. *Absolute and relative increase in skin thickness of morphoea plaques with clinically 'advanced' or 'slight' scleroderma, and increase in thickness of plaques located to the extremities or to the trunk*

S=sclerotic area, C=regional control

	Skin thickness			
	'Advanced' scleroderma, $n=15$		*'Slight' scleroderma, $n=8$*	
	S–C absolute (mm)	S–C relative (%)	S–C absolute (mm)	S–C relative (%)
Mean	1.5	134	0.7	54
Range	0.5–3.1	29–310	0.2–1.0	13–125
	Localted to extremities, $n=10$		*Located to trunk, $n=13$*	
	S–C absolute (mm)	S–C relative (%)	S–C absolute (mm)	S–C relative (%)
Mean	1.6	160	0.9	65
Range	0.7–3.1	100–310	0.2–2.3	13–230

mm in 5 patients. The mean thickness of normal appearing skin of the extensor and flexor aspects of the forearm of 10 patients were 1.0 mm (range 0.8–1.2) and 0.9 mm (range 0.6–1.0), respectively, as compared to 1.0 mm (range 0.8–1.2) and 0.9 mm (range 0.8–1.0) in healthy subjects matched for sex and age. There were no significant differences between these two groups.

Reproducibility and variability studies

Repeated measurements in two typical scleroderma plaques and regional control areas showed SD ranging from 0.05 to 0.09 mm, and coefficients of variation ranging from 3 to 7% with no obvious differences between scleroderma skin and normal appearing skin (Table III). The mean thickness of 10 measurements under water bath performed in the lower extremity of a healthy subject was 1.5 mm (range 1.3–1.7), and with the gelatine plug and slight touch it was 1.5 mm (range 1.5–1.6), i.e. not statistically different. The mean thickness of normal appearing skin was 0.03 mm (1.7%) thinner, and of scleroderma skin 0.19 mm (9.1%) thinner after application of the probe with heavy pressure to the skin instead of slight touch, which might indicate that scleroderma skin is oedematous.

DISCUSSION

The present study shows that scleroderma skin of morphoea plaques is thickened as an obligatory phenomenon in the group of patients examined, in particular in case of clinically 'advanced' scleroderma. The thickness of normal appearing skin of the control regions was the same in both sides of the body, and the thickness of normal appearing skin of a standard region (forearm) of patients with morphoea did not differ from measurements in healthy controls matched for sex and age. The increase in skin thickness was really a local and circumscribed phenomenon in the individual only occurring in skin clinically affected by scleroderma.

The increase in skin thickness was uneven related to the habitual skin thickness, i.e. relatively larger in skin with a habitual thickness of 0.8–1.1 mm. The habitual skin thickness was lower on the extremities (mean 1.0 mm) as compared to the trunk (mean 1.5

Table III. *Reproducibility of ultrasound measurements of skin thickness according to 24 consecutive measurements performed in two typical morphoea plaques, and normal appearing skin of the same region*

	Skin thickness	
	Sclerotic area	Regional control
Abdominal plaque with 'slight' scleroderma		
Mean, mm	1.55	1.13
Range, mm	1.40–1.65	1.05–1.25
SD, mm	0.07	0.05
Variance, $mm^{(2)}$	0.0049	0.0028
Coefficient of variation, %	4.57	4.63
Plaque of the leg with 'advanced' scleroderma		
Mean, mm	2.71	1.33
Range, mm	2.55–2.80	1.20–1.50
SD, mm	0.08	0.09
Variance, $mm^{(2)}$	0.0057	0.0082
Coefficient of variation, %	2.77	6.83

mm), and, consistently, plaques with 'advanced' scleroderma appeared more frequently on the extremities. Patients with the LMP form of localized scleroderma tended to have more plaques with 'advanced' scleroderma as compared to the GM form, and more plaques located to the extremities.

Studies of reproducibility in two typical patients with morphoea showed that measurement of skin thickness of normal appearing skin as well as scleroderma skin with high frequency ultrasound is accurate with a precision close to the level of the ultrasound wavelength. The use of a gelatine plug instead of a water bath had practical advantages and made searching of the more powerful interface echoe easy. The amplitude of the interface echoe depends on the microanatomic surface pattern of the dermis-subcutis interface, and the difference in acoustic impedance between these two tissues. General experience with the ultrasound A-mode apparatus, however, indicated that measurements were less accurate or not possible in regions with many subcutaneous retinacula and a poorly defined tela subcutanea such as the digits, the head, over joints, and occasionally in morphoea plaques too. Obviously, if the dermis-subcutis interface is anatomically poorly defined, precise measurements cannot be obtained with any method. Structural problems in the digits of patients with systemic sclerosis may be overcome by measurement of skin-phalanx distances (1).

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