SKIN ULTRASONOGRAPHY - CLINICAL AND EXPERIMENTAL APPLICATIONS

Monica Gniadecka,MD,PhD* and Jorgen Sondergaard,MD,PhD**

From: the Department of Dermatology, Bioengineering and Skin Research Laboratory, Bispebjerg Hospital, University of Copenhagen, Denmark, and Department of Dermatology, Marfaq Hospital, Abu Dhabi, U.A.E.***

Ultrasound examination of the skin is a relatively new method. Since the introduction in the late seventies by Alexander and Muller[1], this technique is now in a phase of exponential growth. In principle, the high frequency ultrasound wave (over 10 MHz) is emitted off from a transducer, becomes reflected in the skin from the interfaces between media of different acoustic properties, and returns back to the probe. The time lag between the emitted and reflected signal enables to calculate the distance between reflecting objects, whereas the amount of reflected energy characterizes the echogenicity of a given object. Uni-dimensional scanning is referred to as A-mode, whereas two-dimensional scanning is called B-mode scanning. C-mode scanner enables three dimensional imaging[2].

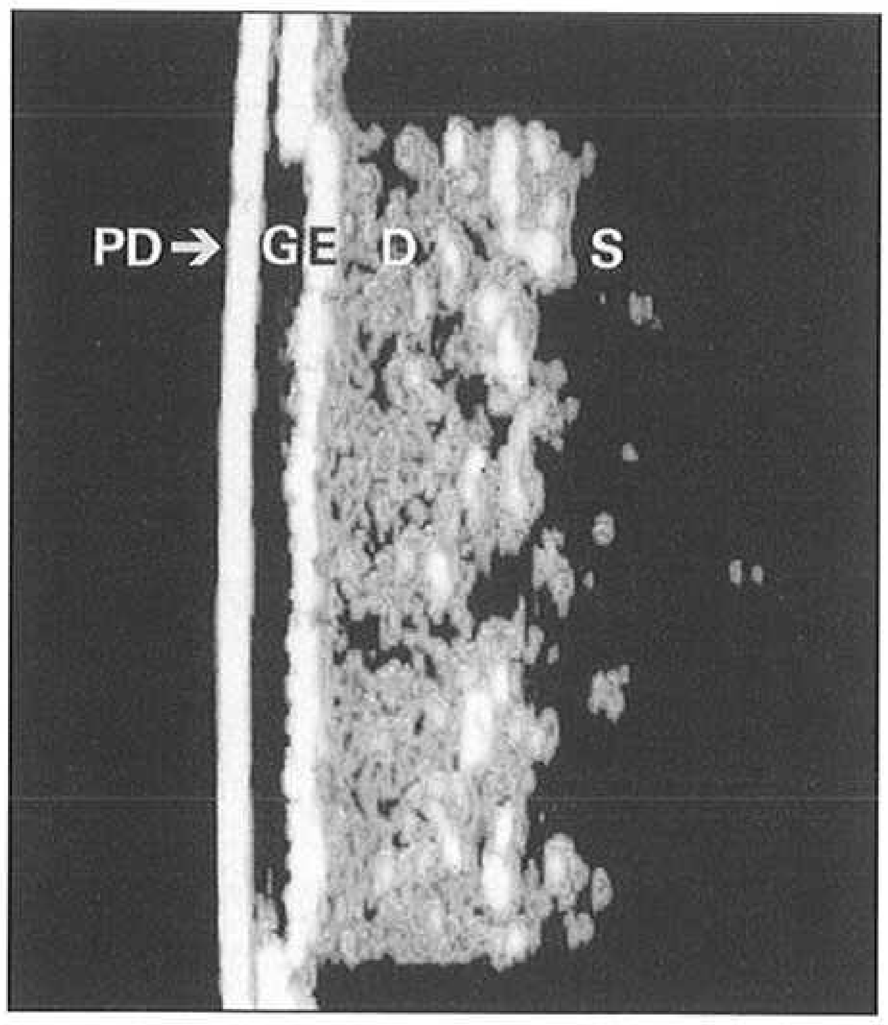

Fig. 1: A representative B-mode ultrasound image of the skin. PD, ultra-thin plastic diaphragm; G, coupling gel; E, epidermal entry echo; D, dermis; S, subcutis.

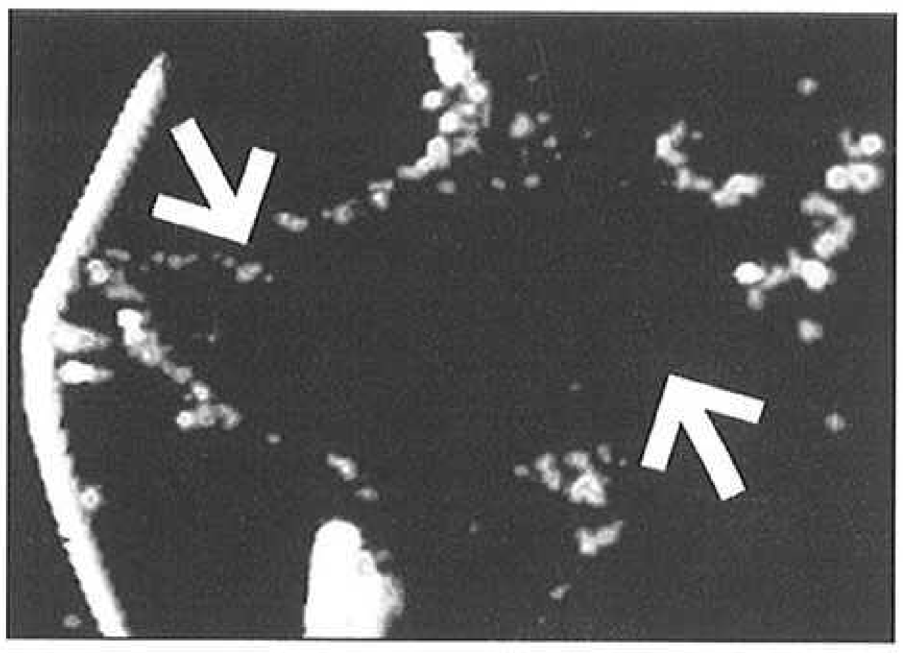

Fig. 2: Ultrasound structure of a scar, arrows-hypoechogenic scar.

The Normal skin-ultrasonogram

Nowadays, B-scanning is used predominantly[3], and in this mode two-dimensional, cross sectional skin image is obtained. The first reflectant layer in the skin is epidermis, the echogenicity of which depends mainly on the thickness of stratum corneum and the amount of air contained between the keratotic scales (Fig. 1). In psoriasis, where hyperkeratosis is prominent, epidermal echo is particularly strong. Dermal echoes are many and variable (Fig. 1). Dermal echogenicity depends on the architecture of skin fiber network and on the amount of contained water. In the neonatal skin and within scars or keloids, echogenicity of the skin drops due to alterations in collagen bundle orientation (Fig. 2)[3-5]. In aged skin a subepidermal low-echogenic band appears, which is related to altered collagen and excess of fluid in the papillary skin. The subcutaneous space is normally low-reflectant. The muscular facia constitutes a highly-reflectant layer, below which a non-reflectant muscular layer may be identified occasionally.

Echogenicity nowadays is amenable for objective quantification with computer-based image analysis programs. Seidenari and DiNardo[6] popularized the system based on the Dermascan C 20 MHz scanner and Dermavision 2D software (Cortex Technology, Hadsund, Denmark). Amplitudes of echoes of single-image elements (pixels) are assigned to discrete values on a numerical scale (0-255). The hypoechogenic band from 0 to 30 represents the hypoechogenic part of the image typical

Correspondence:
Jorgen Sondergaard
Professor of Dermatology
P.O. Box 2951, Abu Dhabi, UAE.

for edema.6-9 The hyperechogenic band from 200 to 255 represents the hyperechogenic part of the image. However, epidermal entrance echo is also highlighted by 200-255 band[6].

The major application of ultrasonography in clinical dermatology are inflammatory skin diseases, connective tissue diseases, post-thrombotic syndrome and cutaneous neoplasms.

Applications of Ultrasonography in Clinical Dermatology

Inflammatory skin diseases

Many ultrasonographic studies has been performed in patients with scleroderma, where course of the disease and efficiency of treatment has been evaluated. In scleroderma, thickening or thinning of the skin is observed, depending on the clinical type of disease and its severity[10,11]. Usually in the early stages the sclerotic plaque is thicker than the normal skin due to inflammatory infiltrate with gradual thinning in the course of the disease. In primary atrophic forms of localized scleroderma (atrophoderma Passini-Pierini) decreased skin thickness is easily measured. In morphea, increased occurrence of echo-rich bands which originate at the dermis-subcutis border and transverse the subcutaneous fatty tissue are found. Follow-up evaluation in both morphea and systemic sclerosis are possible by using the criteria of skin thickness and echogenicity[12].

In inflammatory skin diseases, an inflammatory skin edema is usually visible in the upper dermis as a low-echogenic band. The thickness of this band is proportional to the severity of inflammation. In allergic and irritant reactions, subepidermal band is located superficially and expands to the whole dermis in the wheals of urticaria (Fig. 3). Ultrasound-based quantitation of edema has been used for objective evaluation of patch test reactions[6,13-16].

In psoriasis, skin thickening and subepidermal band are seen, the latter representing inflammatory infiltrate and edema[16]. Scales cause thickening of the epidermal entrance echo and often create shadows. Psoriasis treatment has been monitored by high-frequency ultrasound, where the thickness of subepidermal edema band was measured[17]. Image processing allowed quantification of the progressive reduction in thickness of the dermis and of the hypoechogenic band at skin sites which were locally treated[18].

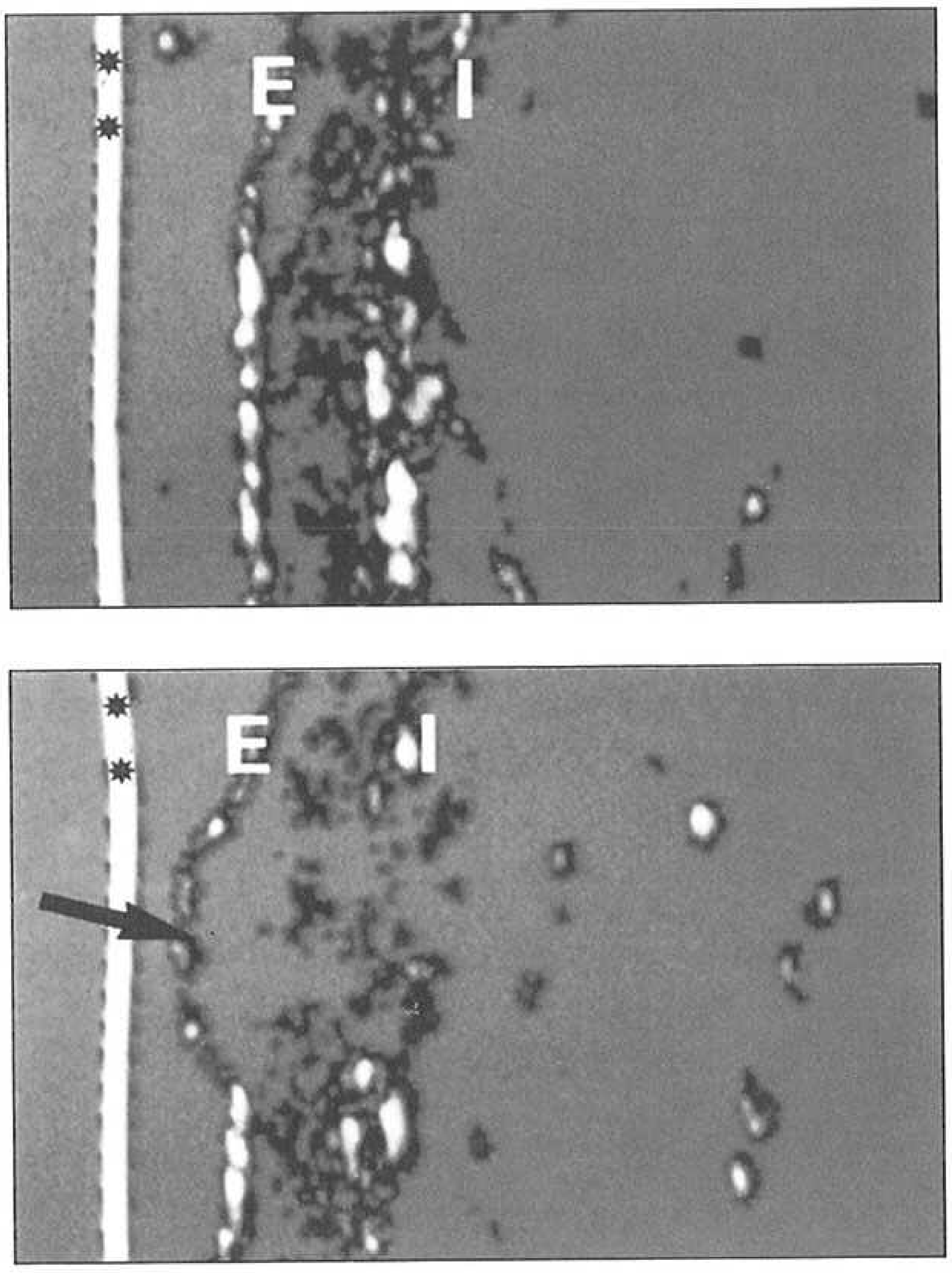

Fig. 3. Ultrasound imaging of the skin before and after injection of histamine. E: epidermis; I: interface between dermis and the subcutaneous tissue. Low echogenic pixels (LEPs) are highlighted in green: Note the formation of a histamine weal, which presents as a water-rich, hypoechogenic area (arrow).

Skin edema

Subepidermal low echogenic band observed in aged skin has been used as a marker of skin ageing[19,20] and probably represents local edema[7].

Because dermal echogenicity is inversely related to the amount of contained water, ultrasound is useful for studying water distribution in normal skin and the formation of edema. With the aid of computerized calculation of echogenicity diurnal fluctuations of water content were demonstrated[8]. Increased venous pressure, precipitated by assumption of the upright posture is associated with water depletion from the skin in young individuals. (Fig.

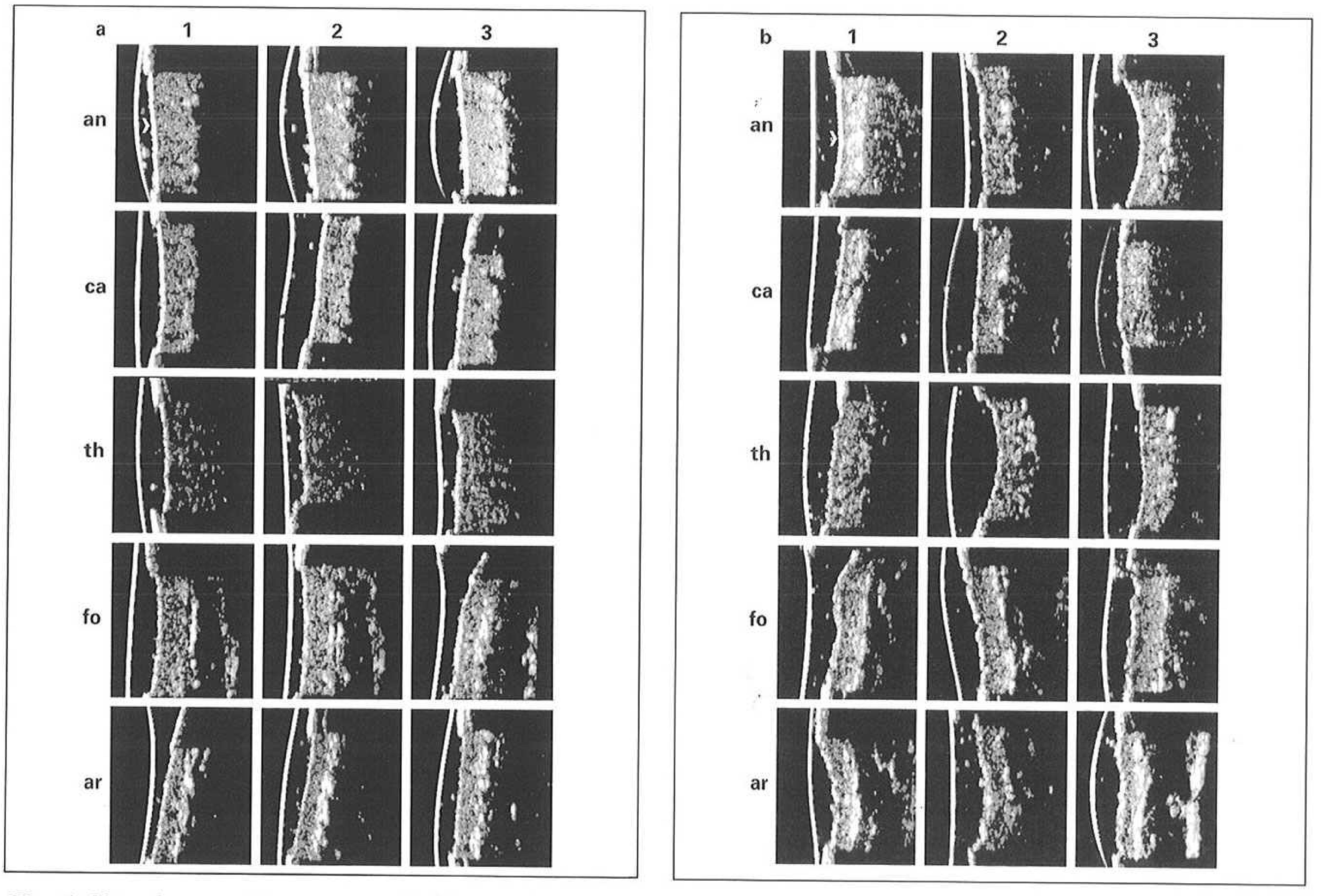

Fig. 4. Skin ultrasound images recorded from different regions of the body of a young (a) and an elderly (b) individual. 1, m, before getting u; 2, 2 h after getting up; 3, 12 hours after getting up. The ultrasound images were obtained from the ankle (an), calf (ca), thigh (th), forearm (fo) and arm (ar). Color scale of echogenicity: white > yellow > red > green > blue > black.The epidermal entrance echo is indicated by (>).

4a) This phenomenon may signify the shift of water from the extravascular compartment in the dermis to the intravascular compartment, thus counteracting hypovolemia developing in the upright position. Lundvall et al.[21,22] postulated that skin may be a reservoir of fluid from which water may be rapidly shifted to the central compartment. In aged individuals this mechanism seems to be defective, since intradermal edema develops after assumption of the upright position (Fig. 4b). Since edema formation in aged individuals in the skin is most pronounced in the ankle region, local mechanisms preventing edema formation become impaired[23,24].

Development of skin edema in deep venous insufficiency was documented[25,26]. Both aggravation of intradermal edema in the upright position and removal of edema by elastic stocking may be monitored by ultrasonography[9] (Fig. 5 and 6). It is still obscure why certain form of edema negatively influence skin metabolism causing necrosis, whereas other forms of edema (lymphedema, edema seen in cardiac insufficiency) are not associated with formation of ulcer. Skin ultrasound can easily play role in future edema research. The minimal effective pressure of compressive regiment for individual patient with leg ulcer can be evaluated with skin ultrasonography. Moreover, ability for imaging of skin edema and its quantification with image analysis give unique opportunities to perform studies comparing efficacy of compressive bandages or supportive stockings.

Skin tumors

Skin tumors present often as structures of lower echogenicity than surrounding healthy dermis. There is an overlap between the internal

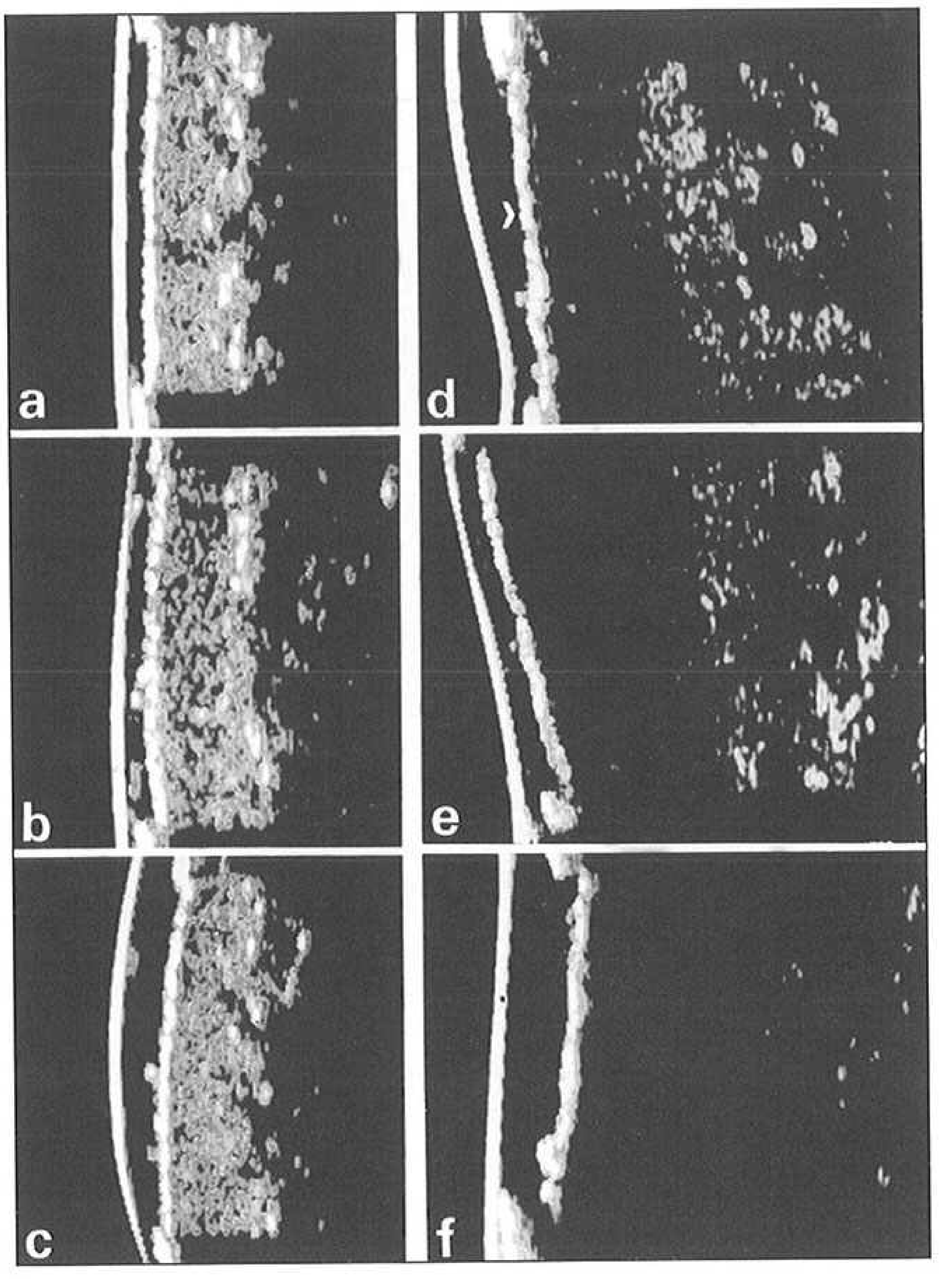

*Fig. 5. Diurnal changes of skin echogenicity. Ultrasound images were recorded from the skin over the medial malleous of a healthy individual (a-c) and a patient with lipodermatosclerosis (d-f). a, d: morning, before getting up; b, e: 2h after getting up; c, f: 12 hours after getting up. In a and d dermis is marked with D, subcutaneous tissue with S. In d: the membrane of the ultrasound probe is marked with **, the epidermal entrance echo with>. Note the widening of the subepidermal low echogenic band in patients with lipodermatosclerosis (arrows).*

echostructure of basal cell carcinoma, squamous cell carcinoma, nevi, and melanoma, and definite differentiation between these tumors on the echostructure basis is impossible. However, qualitative differences between tumors have been discribed[27,28]. Melanoma gives a homogenous echo pattern, while seborrhoeic keratosis are echogenic structures with attenuation beneath tumours[29]. Kaposi's sarcoma consisted of heterogeneous echoes with ill-defined margins. Basal cell carcinoma presented with enhanced echoes below the tumor in ultrasound images[30]. Vascular tumors of skin presented with different echo structures[31]. Lymphangiomata were devoid of echo pattern, and were well defined, while hemangiomata had a poor heterogeneous echo pattern with sharp margins. Architectural detail of lesions on sections corresponds well with that on ultrasound images[27].

Ultrasonography becomes used in the clinic for evaluation of tumor thickness and the depth of invasion, which is helpful in planning surgery[32]. An excellent correlation between histology and ultrasound has shown for maximum tumor depth measurement, but less good for maximum width because of elastic contraction of tissue at excision[27].

A good correlation between preoperative sonographic measurements of melanoma thickness at 10 MHz and histopathological findings has been reported[32,33].

Other possible future applications of skin ultrasonography include monitoring of wound healing and testing of topical pharmaceutical agents and cosmetic products.

Dermatological ultrasound offers not only unique research opportunities but also has significant clinical applications. Further progress in technology will lead to development of higher resolution scanners. High resolution, high-frequency ultrasound may assist the clinical dermatologist in the diagnosis and treatment of skin diseases.

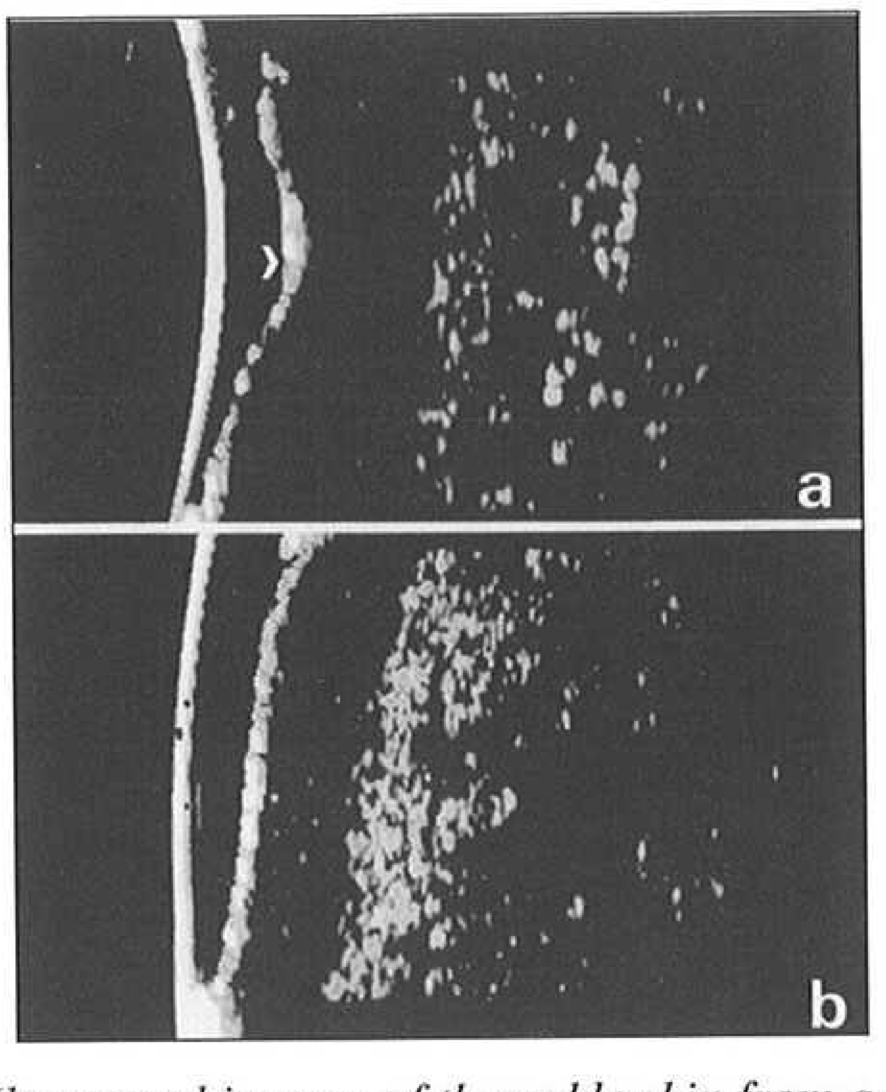

Fig. 6. Ultrasound images of the ankle skin from a patient with lipodermatosclerosis in the morning (a) before and (b) 12 h later after administration of compression. The epidermal entrance echo is marked with> in a. Note the decrease of thickness of the subepidermal low echogenic band after compression therapy.

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