ABSENCE OF DIURNAL CHANGES OF SKIN MECHANICAL PROPERTIES IN PATIENTS WITH LIPODERMATOSCLEROSIS

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Summary:

Gravitational stress is the term describing the physiological and pathophysiological factors and forces triggered by the assumption of the upright posture. Gravitational stress is constantly balanced by protective mechanism, e.g. the muscle pump and the postural vasoconstriction in the microcirculation. We have previously shown that human skin is more stiff and less elastic in the lower extremities forming an "antigravity suit" which protects against gravitational stress. In this study 13 patients with lipodermatosclerosis and 14 control subjects were studied to define the role that skin mechanical properties might play in the pathogenesis of development of venous ulceration. Diurnal changes in skin distensibility, elasticity and hysteresis did not occur, neither in patients with lipodermatosclerosis nor in the control subjects. Absence of the protective diurnal rhythm in skin elasticity may contribute to the poor tolerance of the gravitational stress and lead to exacerbation of gravitational oedema.

Introduction:

In the upright position about 10% of the total blood volume is translocated from the thorax to the lower part of the body and blood pooling and stasis in the lower extremity take place[1]. Blood is collected in the venous system of the legs which causes an increase of venous pressure to 70-100 mmHg[2,3]. This pressure is transmitted to the microcirculation and directly to the skin giving rise to the so called gravitational stress[4,5]. Gravitational stress is thus a term describing all physiological and pathophysiological factors and forces triggered by the assumption of the upright posture.

In the healthy individuals, gravitational stress is constantly balanced by multiple protective mechanisms, the best known being the muscle pump and the postural vasoconstriction in the microcirculation. In old individuals, many of these protective mechanisms are impaired, which leads to the formation of intradermal oedema in the end of the day when cumulative effects of gravitational stress are maximal[6]. Gravitational stress and gravitational oedema affect adversely skin metabolism[4,7,8,].

Skin mechanical properties play a significant role in protection against gravitational stress in tall animals[9]. In giraffes, skin and fascia in the lower extremities is thicker and more stiff than anywhere else in the body, providing support and barrier; preventing formation of gravitational oedema and blancing the gravitational forces. Elastic forces generated in the skin enhance removal of pre-existing oedema in a manner similar to the compressive hosiery. In our previous work we have provided evidence that human skin is more stiff and less elastic in the lower extremities, and proposed that skin forms an 'antigravity suit' which protects against gravitational stress[10]. In aged individuals, the skin is more distensible and less elastic at the level of the ankle, suggesting that in this group the 'antigravity suit' is impaired. We have also observed that skin mechanical properties change during the day, showing a clear diurnal rhythm[10]. In young individuals, distensibility and elasticity of acral skin increases in the end of the day. We regard this phenomenon advantageous because stronger elastic (recoil) forces assist in the removal of oedematous fluid from the skin. Interestingly, these diurnal changes could not be detected in aged individuals, suggesting that gravitational stress is less well compensated in old population.

In patients with deep venous insufficiency where the venous pressure is constantly elevated, gravitational stress is poorly compensated, and has more

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severe consequences being the major factor responsible for the development of lipodermatosclerosis[11]. The features of lipodermatosclerosis are: brownish discolouration of the skin due to haemosiderin formed from haemoglobin from extravasated erythrocytes, intradermal and subcutaneous oedema, formation of pericapillary cuffs of fibrin, and slight to severe fibrosis of the dermis[12,11]. Oedema and fibrin cuffs impair skin metabolism, leading to the formation of leg ulcer[4]. In this work we measured diurnal changes in skin mechanical properties in individuals with lipodermatosclerosis, and discuss possible consequences of our findings with regard to skin biomechanics and the pathogenesis of leg oedema and development of venous ulceration.

Patients And Methods:

Volunteer

Two groups of volunteers were studied: (1) patients with lipodermatosclerosis - 13 individuals, mean age 80; (2) 14 age-matched volunteers - mean age 79, without haemodynamic significant pathologies of the cardiovascular system. Lipodermatosclerosis was defined according to the criteria published before as an area of brown discolouration located over the medial malleolus[11]. All participants gave their informed consent to take part in the study. Ethical approval for the study was given by the Ethical Committee of Copenhagen Municipality.

Measurement of Skin Mechanical Properties

To measure skin mechanical properties, Dermaflex A (Cortex Technology, Hadsund, Denmark) was used. The detailed des-cription of the equipment and the principle of the instrument has been des-cribed extensively before[13]. Briefly, Dermaflex A consists of a suction probe coupled to a vacuum-generator and the data elaboration and visualisation system. The suction probe is placed on the skin where it exerts a series of negative pressure cycles. In this experiment, the equipment was set to exert a negative pressure of 450 mBar in 5 cycles of 20 s each. Skin elevation is measured on-line during the suction cycle, and three parameters are calculated: distensibility (maximal skin elevation in the end of the first suction), resilient distension (residual skin elevation after the release of the first suction:), and hysteresis (increase in skin distensibility at repeated suctions, a creeping phenomenon). From these primary parameters the value of elasticity (relative elastic retraction) may be calculated as follows:

Elasticity = [(distensibility-resilient distention) divide by (distensibility)] multiplied by 100%

A 100% value of elasticity means the perfect recovery of skin shape after stretch.

The Design of the Study

Measurements were taken in the supine position twice daily - in the morning just after waking up but before standing up, and 12 hr later in the evening. Distensibility, elasticity and hysteresis were measured in the region 5 cm over the medial and lateral malleolus and 5 cm below the level of the knee on the lateral side of the calf. Both measurements were made exactly from the same sites of the skin. For data analysis, the afternoon value was subtracted from the morning value. Such obtained data were compared within the group with a single-sample t-test, and across the groups with an unpaired two-sample t-test.

Results

Results of the study are shown in Table 1. Neither in the patients with lipodermatosclerosis nor in normal subjects did the mechnical properties of the skin (distensibility,

Table 1 - Diurnal Changes of Elasticity, Distensibility and Hysteresis in Patients with Lipodermatosclerosis and the Control Subjects:

	ELASTICITY	DISTENSIBILITY	HYSTERESIS
Lipodermatosclerosis			
Medial Malleolus*	2.69 ± 11.67	0.153 ± 0.424	0.026 ± 0.214
Lateral Malleolus	0.77 ± 12.24	-0.151 ± 0.58	0.005 ± 0.206
Calf	5.61 ± 10.42	-0.105 ± 0.399	-0.107 ± 0.299
Control			
Medial Malleolus	3.85 ± 16.81	0.313 ± 0.841	-0.031 ± 0.333
Lateral Malleolus	0.95 ± 11.13	0.009 ± 0.193	-0.001 ± 0.291
Calf	4.98 ± 15.55	-0.116 ± 0.511	-0.203 ± 0.139

* regions with lipodermatosclerosis

elasticity and hysteresis) change during theday (single-sample t-test vs. 0, p>0.05). Differences between the groups with lipodermato-sclerosis and normal controls were not detected (two-sample t-test).

Discussion

In humans, skin in the lower extremities is more stiff than anywhere else in the body which allows compensation for the increased gravitational stress in the upright position and prevents venous distention[10]. The stiffness of the skin is expressed in biomechanics by the value of distensibility, which is qualitatively different from elasticity. The latter term describes the ability to recover shape after stretch. Elasticity of the skin may be an important factor contributing to the clearance of intradermal oedema. In healthy young individuals, elasticity increases in the evening when the amount of water (gravitational oedema) in the skin is maximal.

Patients with deep venous insufficiency have a severely increased venous pressure in the upright position due to the damage in venous valves. Therefore, in these patients the effect of gravitational stress on the skin are much greater than in the normal counterparts. The morphological equivalent of the effects of gravitational stress on the skin in deep venous insufficiency is lipodermatosclerosis[11,5]. In this work we have analysed the diurnal changes of skin mechanical properties in patients with lipodermatosclerosis and compared them with those observed in healthy, age-matched controls. Such analysis was interesting for us for two reasons. First, it has not been clear whether diurnal changes of skin mechanical properties represent an intrinsic diurnal rhythm or are rather dependent on, and modulated by gravitational oedema. In the latter instance, differences in diurnal rhythms between patients and controls should be detected because skin in lipodermatosclerosis contains excessive amount of oedematous fluid. Secondly, as discussed above, the increase of elasticity in the afternoon may be beneficial for eradication of oedema. The absence of this phenomenon in patients with lipodermatosclerosis could, therefore, further enhance the accumulation of oedema in the lower extremity.

Our results show that diurnal changes in skin distensibility, elasticity or hysteresis do not occur neither in patients with lipodermatosclerosis nor in the control subjects. It is therefore, unlikely that oedema is a factor governing the occurrence of diurnal changes in skin mechanical properties. Absence of the protective diurnal rhythm in skin elasticity may contribute to the poor tolerance of the gravitational stress and exacerbation of gravitational oedema. The importance of this notion lies in a fact that formation of leg ulcers is enhanced by leg oedema. Interestingly, no diurnal change in hysteresis has been detected. Biological significance of hysteresis has not been elucidated, but it has been shown in a histamine wheal model that in states of skin oedema the value of hysteresis is increased[14,13]. However, despite known diurnal increase in intradermal oedema in aged individuals and patients with lipodermatosclerosis, hysteresis of skin did not change[15]. There may be two explanations of this fact. First, our measurements might not have been sensitive enough to detect fluctuations in fluid content in the skin. Secondly, the nature of oedema seen in lipodermatosclerosis may differ from that seen in histamine wheals. We have recently observed that in lipodermatosclerosis oedema is confined mostly to the upper part of the dermis; whereas in the histamine wheals, fluid is distributed evenly in the whole dermis (Gniadecka, M. - unpublished). Therefore different forms of oedema may differently affect the biomechanic properties of the human skin.

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