

## USE OF TONOMETRY TO ASSESS LOWER EXTREMITY LYMPHEDEMA

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### ABSTRACT

*Tissue tonometry was used to assess the outcome of microwave hyperthermia in treatment of 9 patients with lower extremity lymphedema. After microwave treatment, tissue tonicity of the lymphedematous leg returned toward normal. This improvement correlated with a reduction of leg volume and circumference, decrease in "inflammation" in the edematous subcutaneous tissue and clinical episodes of cellulitis. Possible factors involved in this shift in tissue tonicity toward normal include mobilization of excess fluid and plasma proteins from the interstitium, reduction in microvascular cellular infiltrate and changes in the elastic and viscoelastic properties of matrix collagen, elastin and ground substance following hyperthermia.*

A tissue tonometer is a useful device for determining dermal-subcutaneous tonicity in limb lymphedema (1-4). Tonicity is defined as the degree of tissue resistance to mechanical compression. Clodius, Piller and their colleagues (1,2) have reported that lymphedematous tissue over time becomes more resistant to compression and shows some improvement (i.e., less resistance) after treatment with benzopyrone drugs. Chen et al (4) also used tonometry to show greater tissue softness after lymph-venous anastomosis for treatment of upper extremity chronic lymphedema.

In this study, we describe tonometric measurements used to complement limb volume monitoring after use of microwave hyperthermia in treatment of leg lymphedema.

### MATERIALS AND METHODS

The population study included 9 patients with lower limb obstructive lymphedema—mean duration 16 years. The microwave oven used had a working frequency of 2450 MHz. The highest temperature was recorded in the subcutis of the treated limb and reached approximately 40°C during treatment. The treatment time was for 45 min daily for 15 days and then the cycle was repeated 3x after 7 days respite. After each treatment period and during the intermission interval, compression bandages were continuously worn by the subjects during the day. Tissue tonicity, limb volume and circumference were measured on both the affected and contralateral (normal) leg. Leg volume was determined by water volume displacement and the leg circumference was measured at four sites (for details, see reference 5). Skin specimens were obtained for histology on the lymphedematous leg. The follow-up period was up to 12 months after completion of 3 courses of microwave therapy.

The tonometry (COMPAC Switzerland) used has a central flat plunger, a foot plate

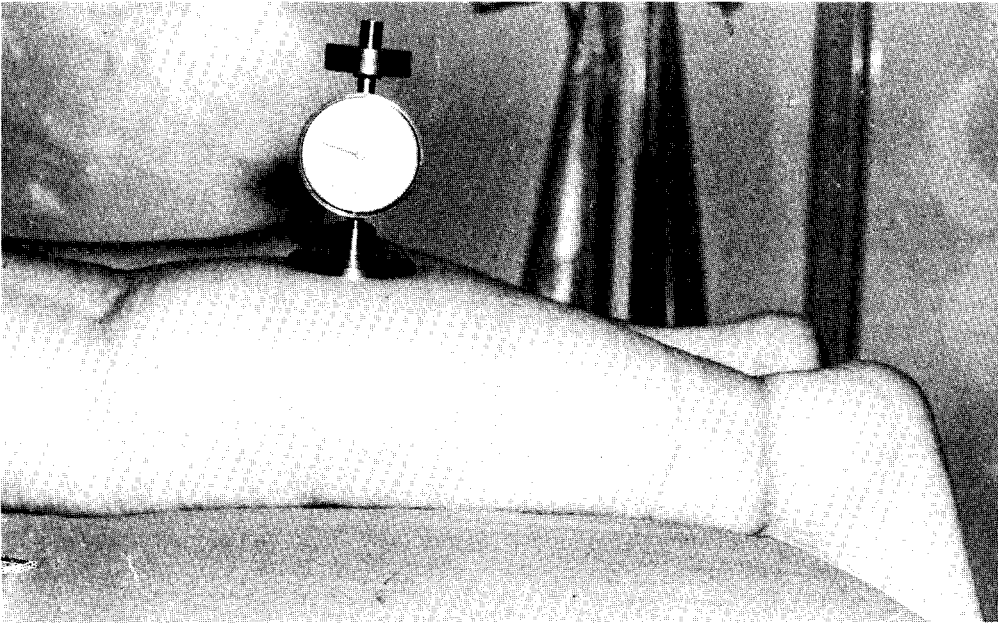


Fig. 1. Tonometer used to test tissue tonicity.

and a gauge (Fig. 1). Three weights (34.3, 68.7, 68.9g) are added to the central column. The descent of the plunger causes the needle to sweep around the dial and the "deformation" is measured in millimeters. During the test, patients are prone and the muscles of the leg are relaxed. The instrument is placed on the medial part of the calf as this site is reasonably flat. In order to make the measurement as accurate as possible, it is imperative not to handle the instrument during measurements. After applying the weights, depressions are recorded at 3 sites after 5 min of observation, and an average value is taken. A similar procedure is carried out on the non-edematous contralateral leg and the latter values are taken as a reference for "normal." Student t test was used for statistical comparative analysis with  $p < 0.05$  taken as "significant."

## RESULTS

After a full course of microwave treatment, the volume and circumference of the lymphedematous leg was reduced in each

patient with a mean value of 155ml ( $p < 0.05$ ) and 11.32cm ( $p < 0.05$ ), respectively. No infection (lymphangitis-cellulitis) occurred during the treatment and post-treatment follow-up period. Before microwave treatment, 5 of the 9 patients had lower tonometric value on the edematous leg (i.e., softer than the normal contralateral leg). After treatment, however, tissue tonicity increased in 4 of these 5 patients and in one patient the tonicity became even higher than normal (i.e., compared with the contralateral non-edematous leg). Among the 4 patients treated with microwave hyperthermia who had higher value for tonicity on the edematous leg (i.e., firmer than normal), tissue tonicity decreased in 3 and increased in one. Fig. 2 shows the differences of tissue tonicity between edematous and contralateral legs using 3 different weights. For further comparison, the tissue tonicity of both lower legs of 5 normal volunteers was obtained. Before treatment the difference of tonicity was notable from that of normal volunteers. However, this difference was reduced after treatment using

all 3 weights with a mean±SD value of  $0.030\pm 0.014\text{mm}$ ;  $0.066\pm 0.021\text{mm}$  and  $0.048\pm 0.015\text{mm}$ , respectively ( $p<0.05$  for each comparison). The tissue tonicity of the lymphedematous leg returned either to normal or near normal.

On histology of skin biopsies before and after microwave treatment there was uniform resolution of perivascular cellular infiltrate in the edematous leg and disappearance of accumulated free fluid ("lymph lakes") in the subcutaneous tissue (5).

## DISCUSSION

Measurement of tissue tonicity helps determine the "turgor" of the skin and subcutaneous tissue. The interstitial space contains liquid, solid elements such as collagen and elastin fibers, and gel or gel-like ground substances composed primarily of mucopolysaccharides. Together these components determine tissue tonicity. Collagen, elastin, and their structural arrangement account for the "elastic" properties of the skin and subcutis whereas the ground substances determine its viscoelastic properties (6). Tissue tonicity varies with site, age, and sex (7,8). The interstitium of lymphedematous tissue contains an excessive amount of proteinaceous fluid, which exerts within the solid elements a certain degree of stress-strain

which decreases tissue elasticity and ground substance viscosity. With lymphedema the relative volume of tissue collagen fibers and fat cells are increased whereas that of ground substance is reduced (9). Because lymphedema subcutaneous-dermis tissue has decreased elasticity, it is more resistant to compression.

Another noteworthy pathologic change in lymphedematous tissue is acute and chronic inflammation which sometimes is complicated by overt infection. During an episode of lymphangitis-cellulitis, tissue tonicity rises significantly (4). The cellular infiltration in the subcutis and dermis may contribute to the altered tissue tonicity with lymphedema. In the present study, the tonicity of the lymphedematous differed significantly from that of normal and in fact varied with the degree of lymphedema. In 4 patients, tissue tonicity was higher (i.e., harder) than that of the contralateral leg, whereas in 5 the lymphedematous leg was softer. Such variation may relate to the differing cause of lymphedema, duration of swelling, extent of edema, and histopathologic change in the affected leg. Thus, a leg tight with edema fluid is almost incompressible, but one less swollen is more easily compressed. Moreover, the greater the edema when first measured, the greater the improvement in compression when this fluid is effectively mobilized. Finally, a leg with

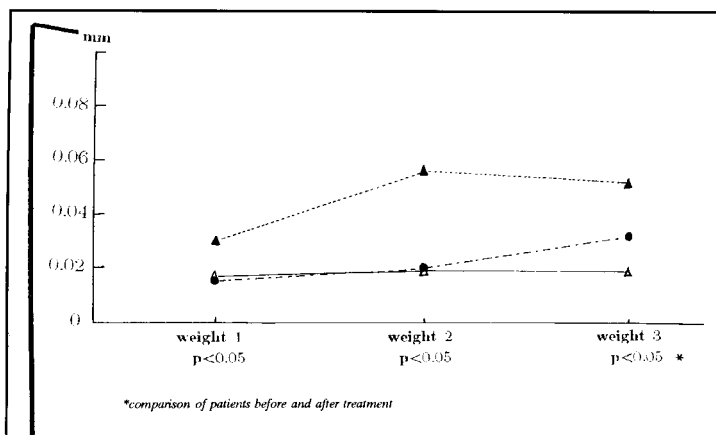


Fig. 2. Differences of tissue tonicity (at 3 weight compressions) between legs of 9 patients with unilateral lymphedema before and after hyperthermia and between legs of 5 volunteers. Note that after lymphedema treatment, the difference in leg tonicity is closer to normal.  $\Delta$ —normal;  $\blacktriangle$ —lymphedema before treatment;  $\bullet$ —lymphedema after treatment.

diffuse fibrosis also tends to have low compressibility (3).

After microwave hyperthermic treatment, leg tissue tonicity changed dramatically, irrespective of whether the initial values were above or below that of the contralateral leg before treatment. The values returned toward normal (i.e., higher became lower and lower became higher) and the differences between the unaffected and affected legs sharply narrowed. This outcome coincided with a dramatic reduction in volume and circumference and less skin "inflammation" on histology.

Because tonicity depends on a multitude of soft tissue factors, it is likely that the biological mechanisms for changes after hyperthermia are multifactorial. As leg volume and circumference decreased, mobilization of excess tissue protein and fluid from the interstitium could account for tonicity change. This hypothesis is suggested by the histological finding whereby "lymph lakes" or accumulated tissue fluid in the subcutaneous tissue disappeared after microwave therapy. Another plausible explanation for change in tonicity may relate to reduction in "inflammation" in the lymphedematous leg. Before treatment, many patients had repeated cellulitis but no infectious episodes occurred during or after hyperthermia. Whereas there was intense microvascular infiltrate in the lymphedematous skin before treatment, the density decreased prominently after microwave treatment.

Until now, limb volumetric and circumferential measurements have been the most commonly used objective methods to evaluate peripheral lymphedema. In contrast to the "conventional" methods, tonicity provides insight into the status of soft tissue structure and its mechanical behavior that varies with edema severity (8). Our study demonstrates that alteration in

tissue tonicity parallels subsidence of soft tissue swelling and improved histology in legs with lymphedema. Tissue tonometry is therefore a useful and reliable method for following peripheral lymphedema before and after treatment.

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