

Lymphedema Assessment by Local Tissue Water and Indentation Resistance

Purpose: Changes in tissue water and the tissue's resistance to indentation accompany lymphedema but the relationship between these changes, if any, is unclear. Because these lymphedema-related changes are not generally uniform it is useful to be able to noninvasively assess these parameters locally at sites of clinical interest. Local tissue water (LTW) is quantifiable using the tissue's dielectric constant (TDC) since its value increases with tissue water content. TDC measures have been reported as useful for routine clinical assessments. However, a handheld clinical assessment tool to routinely quantify corresponding local tissue indentation resistance (TIR) in a way that does not depend on device orientation (gravity-independent) is not widely available. Thus, the goals of this research were to: 1) develop a simple portable device for routine clinic assessment of TIR in patients with lymphedema, 2) determine if LTW and TIR were related and 3) determine the effect of a single manual lymphatic drainage (MLD) treatment on these parameters.

Methods: The self-contained device has a 10 mm diameter indenter coupled to a mechanical force indicator. Indentations (1 to 4 mm) were done and resultant indentation forces (FORCE) recorded using gels, foams and both legs of 12 persons with no history of lower extremity abnormalities. These were done to assess measurement linearity and repeatability. Thereafter, FORCE and TDC were measured in 22 legs of 18 patients with lower extremity lymphedema prior to and after they received one MLD treatment.

Results: The in vitro gel and foam tests and the tests on healthy legs demonstrated that for the indentation range used FORCE was linearly related to indentation depth ($r=0.995$) with a coefficient of variation less than 5%. Measurements of lymphedematous legs showed that prior to MLD treatment both FORCE and TDC were significantly ($p<0.001$) greater in lymphedematous legs compared to healthy legs and that both FORCE and TDC significantly ($p<0.001$) decreased after MLD. Despite treatment-related reductions in both FORCE and TDC these parameters were not correlated ($r=-0.067$).

Conclusions: Use of the self-contained handheld device allowed assessment of tissue resistance in about 10 seconds thus providing a rapid index of lymphedematous tissue resistance. Since device operation is gravity-independent it could be applied at any orientation and be used on any body part. Its use combined with LTW measurements showed that compared to legs of subjects without lymphedema, lymphedema presence was associated with significantly greater tissue resistance as judged by indentation FORCE and a greater LTW as judged by the greater TDC. Although both TDC and FORCE decreased with MLD treatment changes were not correlated with each other.

Clinical Relevance: Local tissue resistance and tissue water provide useful but apparently independent information as to the lymphedematous condition and its potential change with therapy. The combination offers a way to assess initial and progressive treatment-related changes in fluid and fibrotic status.

Key Words: lymphedema measurement, edema measurement, lymphedema treatment, dielectric constant, tissue water, leg lymphedema, manual lymphatic drainage, MLD, tonometry, tissue mechanical properties