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LIMB CIRCUMFERENCE MEASUREMENT FOR RECORDING EDEMA VOLUME IN PATIENTS WITH FILARIAL LYMPHEDEMA

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ABSTRACT

To evaluate the impact of therapy and monitor the progression of filarial lymphedema, it is necessary to measure accurately the changes in limb edema volume. In this communication, we report the reliability of circumference measurements for recording volume changes. The measurements included the distal parts of limbs important for filarial lymphedema. In a series of 100 patients with unilateral lower limb lymphedema, both water displacement and circumference measurements were done. The results showed a significant correlation (r=0.91; P=0.0000) between the actual volume and that estimated by circumference measurement. Not only could volume of edema be calculated by circumference measurements, but the simple measurement of average circumference difference between the affected and normal limb accurately reflected the volume of actual edema.

Lymphatic filariasis is an important public health problem in many developing countries including India (1). Lymphedema is the most disfiguring manifestation responsible for physical suffering (2,3) and socio-economic burden (4,5). For developing sound principles of management of lymphedema, it is essential to evolve an easy, simple and practical field applicable objective and reliable method of measuring edema volume over time. The method of volumetry using water displacement is relatively simple and easily used in the hospital or clinic setting (6,7). However, it is difficult to use in more remote areas in the field and is unsuitable for patients with skin ulcerations. Measurement of circumference at different fixed points of an edematous limb on the other hand is also simple. The technique of indirect volume measurement by circumference differences of the limb developed in earlier studies used measurements taken above the ankle or wrist only (8-10). In this communication, we report a technique which includes the foot and is suitable specifically for patients with filarial lymphedema of lower limbs.

MATERIALS AND METHODS

In 100 patients with unilateral lower limb filarial lymphedema who attended the Filariasis clinic at the Vector Control Research Centre, Pondicherry, the following measurements were taken:

A. Circumference measurements *(Fig. 1)*: Length measurements L1, L2, L3 and circumference measurements at levels C1 to C7. The position of C2 was 10 cm from 0 (tip of great toe), the positions of C5, C6 and C7 were at 12, 20 and 30 cm from level of ground (00). The levels of C1, C3 and C4 were different in each patient depending on anatomical variations. All measurements were made in centimeters.

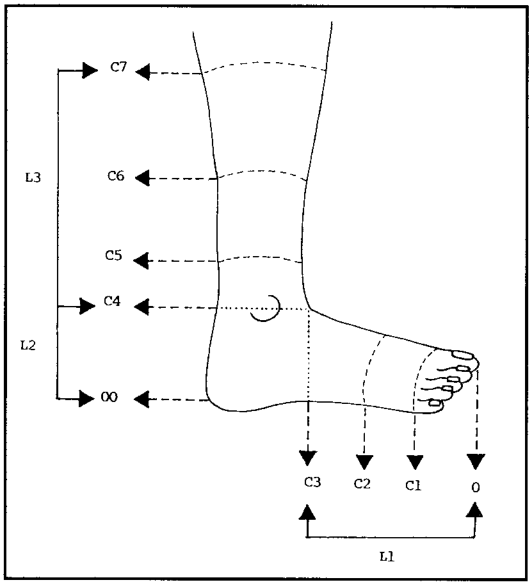

Fig. 1. Measurements at different levels of lower limb: 00 - level of ground; 0 - tip of great toe; C1 - base of metatarso-phalangeal joints; C2 - 10 cms from 0; C3 - mid-tarsal line through most proximal part of dorsum of foot; C4 - line through midpoint of lateral malleolus; C5 - 12 cms from 00; C6 - 20 cms from 00; C7 - 30 cms from 00. L1 - length from 0 to C3; L2 - length from 00 to C4; and L3 - length from C4 to C7.

B. Volumetry using water displacement up to the level of L3 incorporated a simple technique with facility to measure the level of water with a locally designed steel drum. Thus, the height of limb considered was identical both for circumference measurement and water displacement.

Measurements described in A and B were taken both for the edematous (affected) and the contralateral (normal) limb.

Calculations:

A. Circumference Measurements (CM) *(see Fig. 1)*:

1. Average circumference: Mean of C1 to C7. This determination was separately derived for both the affected and normal limb and termed as affected mean circumference (AMC) and normal mean circumference (NMC) respectively.

2. Calculation of limb volume from circumference measurements: For this purpose, the limb up to the level of C7 was divided into three parts.

a. Portion from C4 to C7 was taken as a cylinder (cyl-1) with a length of L3 and circumference, which was the average of C4 to C7 formed as Avccyl-1.

b. Portion from C3 to C4 was approximated by a cylinder (cyl-2) measuring length L2 and circumference of C4.

c. Portion from the toes to the level up to C3, which was taken to be half the volume of a rectangular cube with L1 and L2 as the length and the breadth of the cube respectively.

The volumes of the above three parts were calculated separately (as V1, V2 and V3, respectively) as follows:

$$V1 = \pi \times (\text{Avccyl-1}/2\pi)^2 \times L3$$

$$V2 = \pi \times (C4/2\pi)^2 \times L2$$

$$V3 = (L1 \times L2 \times L2)/2$$

The total limb volume was derived by adding the volumes of the above three portions. By circumference measurements, the total limb volume for the affected and normal limb was calculated separately (termed as ALV-CM and NLV-CM, respectively) for each patient. The volume of edema was calculated as the difference of ALV-CM and NLV-CM for each patient and termed edema volume (EV-CM).

B. Volumetry by Water Displacement (WD):

The volume for the affected and

TABLE 1
Average Circumference Measurement (cms) and Volume of Water (ml) Along with (±) Standard Error for Normal and Affected Limb of Three Grades of Lymphedema in Patients with Filariasis

	Grade I	Grade II	Grade III
Number of patients	35	56	9
Mean duration (months)	2.5±0.5	50±7.0	85±19.2
Mean circumference (cms)			
Affected limb	24.3±0.33	26.2±0.38	27.4±1.20
Normal limb	23.2±0.32	23.1±0.24	23.2±0.48
Mean volume by water displacement (ml)			
Affected limb	2109±124	2596±128	2844±325
Normal limb	1900±120	1925±89	2005±188
Mean volume by circumference (ml)			
Affected limb	1909±51	2241±71	2433±208
Normal limb	1715±53	1701±33	1705±84

normal limb were obtained directly by water displacement and termed as ALV-WD and NLV-WD, respectively. The edema volume was the difference of the above two measurements and termed as EV-WD.

C. Analyses of Relationships:

1. At first, the correlation between average circumference and actual volumes by water displacement was examined, both for the affected and normal limb (relationship between AMC and ALV-WD and between NMC and NLV-WD).

2. Next, the correlation between limb volume estimated from circumference measurements and that from water displacement was studied both for affected and normal limbs (relationship between ALV-CM and ALV-WD and NLV-CM and NLV-WD).

3. Subsequently, the correlation between the edema volume as obtained by circumference measurements and that obtained by direct water displacement was studied (relationship between EM-CM and EV-WD).

4. The correlation as described in above (#3) was obtained separately for three grades of edema (relationship between EV-CM and EV-WD for Grade I, II and III patients separately), to determine if the relationship holds with different degrees (severity) of edema.

RESULTS

The mean circumference and mean limb volumes obtained by water displacement or that obtained by circumference measurements for normal and affected limbs in three grades of edema are shown in *Table 1.* The mean duration of edema increased from 0.2 (± 0.2) years in grade I patients to 4.2 (± 4.2) years in

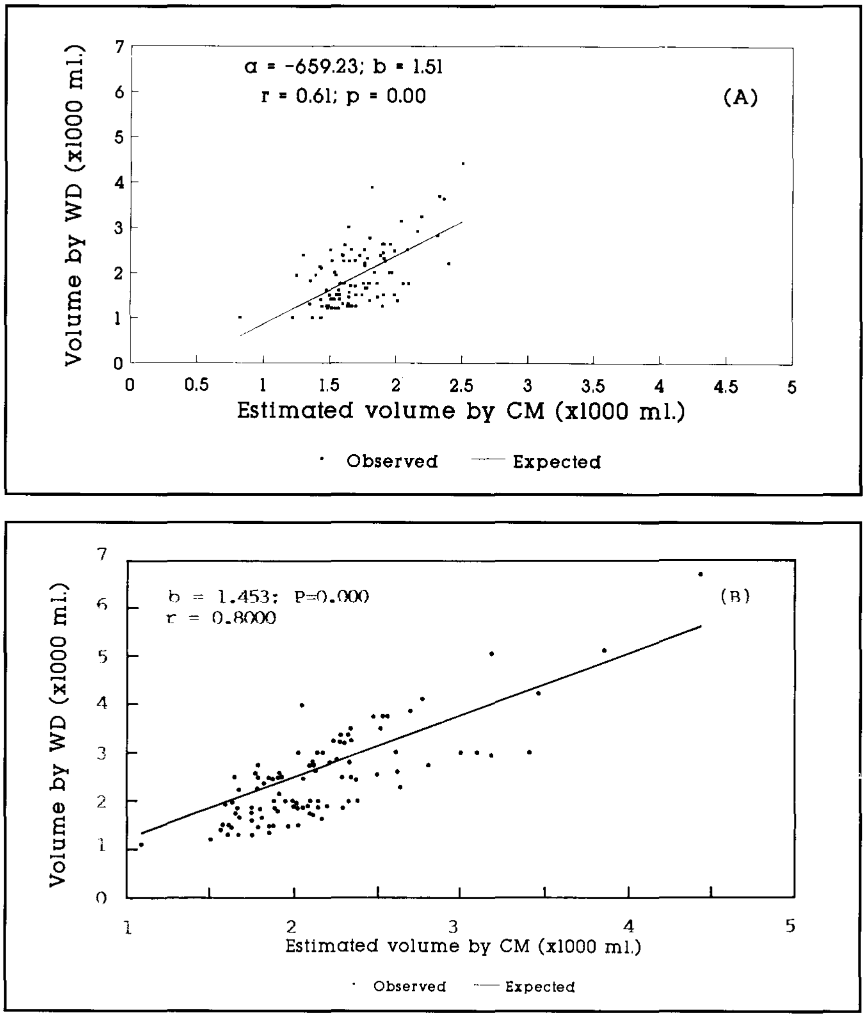

Fig. 2. Relationship between estimated volume by circumference measurement (CM) and volume by water displacement (WD). A - normal limb; B - affected limb.

grade II patients which increased in turn to 7.0 (± 4.5) years in grade III patients. The edema volume (the difference between affected and normal limb volume) increased from 209 (± 153) ml in grade I patients to 671 (± 696) in grade II patients and to 839 (± 752) ml in grade III patients.

A significant correlation was observed between the average mean circumference and limb volume measured by water displacement both for the affected and normal limb (for normal limb: intercept (a) = -2735.85; slope (b) = 201.26; r = 0.55; p = 0.00 and for affected limb: a = -3769.79; b = 241.69; r = 0.75; p = 0.00). The correlation between the limb volumes as measured by circumference measurements and that by water displacement was also significant, both for affected and normal limbs (for normal limb: a = -659.23; b = 1.51; r = 0.61; p = 0.00 for affected limb: a = -664.88; b = 1.45; r = 0.80; p = 0.00; *Fig. 2*), although the volume by water displacement was consistently slightly higher. Analyses of correlation of edema volume (difference between the affected and normal limb volume) by circumference measurements and that by water displacement was also highly significant (a = -32.14; b = 1.27; r = 0.91; p = 0.00; *Fig. 3*). The goodness of fit of the equation was

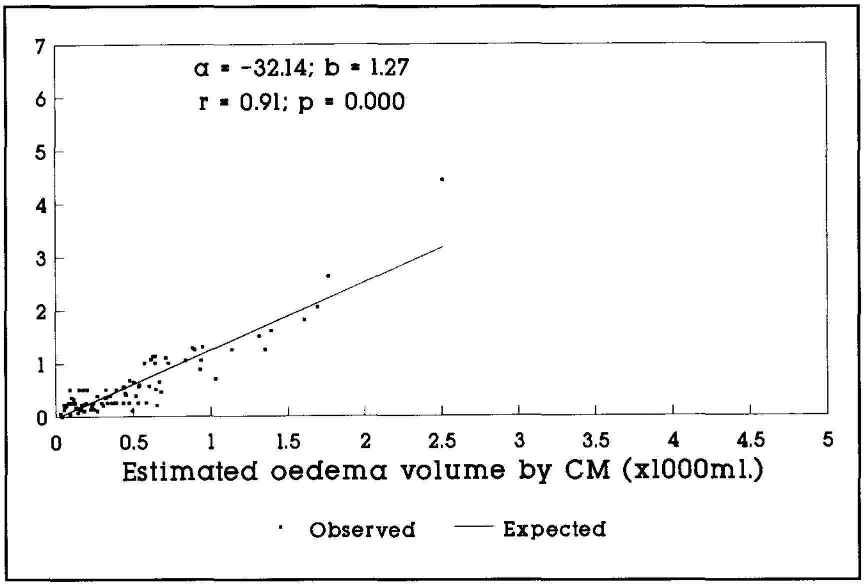

Fig. 3. Relationship between estimated edema volume by circumference measurement and edema volume by water displacement.

examined by calculating the correlation coefficient between fitted values and residuals following the method of Draper and Smith (11). The correlation coefficient ($r = 0.00$) described the relationship. The analysis showed that 80% of the predicted values (volume by circumference) were within ± 15% of the true values (volume by water displacement).

Analyses of correlation of the above edema volumes in three grades of edema as measured by water displacement and that by circumference measurement was also significant (for grade I: $a = 135.71$; $b = 0.38$; $r = 0.45$; $p < 0.001$, for grade II: $a = -55.08$; $b = 1.34$; $r = 0.92$; $p = 0.00$, for grade III: $a = -163.49$; $b = 1.38$; $r = 0.92$; $p = 0.0005$; *Fig. 4*). Further, a significant correlation was observed between the mean difference of affected and normal limbs (AMC-NMC) and the mean edema volume by water displacement (EV-WD) ($a = -76.13$; $b = 233.13$; $r = 0.91$; $p = 0.000$).

DISCUSSION

Filarial lymphedema results in two cardinal signs: (a) increase in volume of the affected limb, and (b) increase in limb tonicity. Whereas (a) reflects the gross increase in limb tissue and fluid volume, (b) represents the degree of skin pathology. The effect of treatment on prognosis should be assessed by measuring both parameters. Tonicity is measurable using a tonometer (12,13), although limb volume increase does not directly correlate with tonometry (13). Therefore, limb changes should be independently measured for both phenomena. This communication deals principally with the change in edema volume.

Direct measurement of edema volume can be done by water displacement or by computer assisted tomography or optoelectronic methods (10). The disadvantages of using water displacement (difficult in the "field" or with skin ulcerations) has already been pointed out. The latter two techniques require sophisticated and costly instruments not suitable or adaptable for developing countries. Circumference measurements, on the other hand, are simple and can be done accordingly by the patient in his or her own home. Previous calculations (8-10) using circumference measurements, though suitable for lymphedema that follows radical operations is

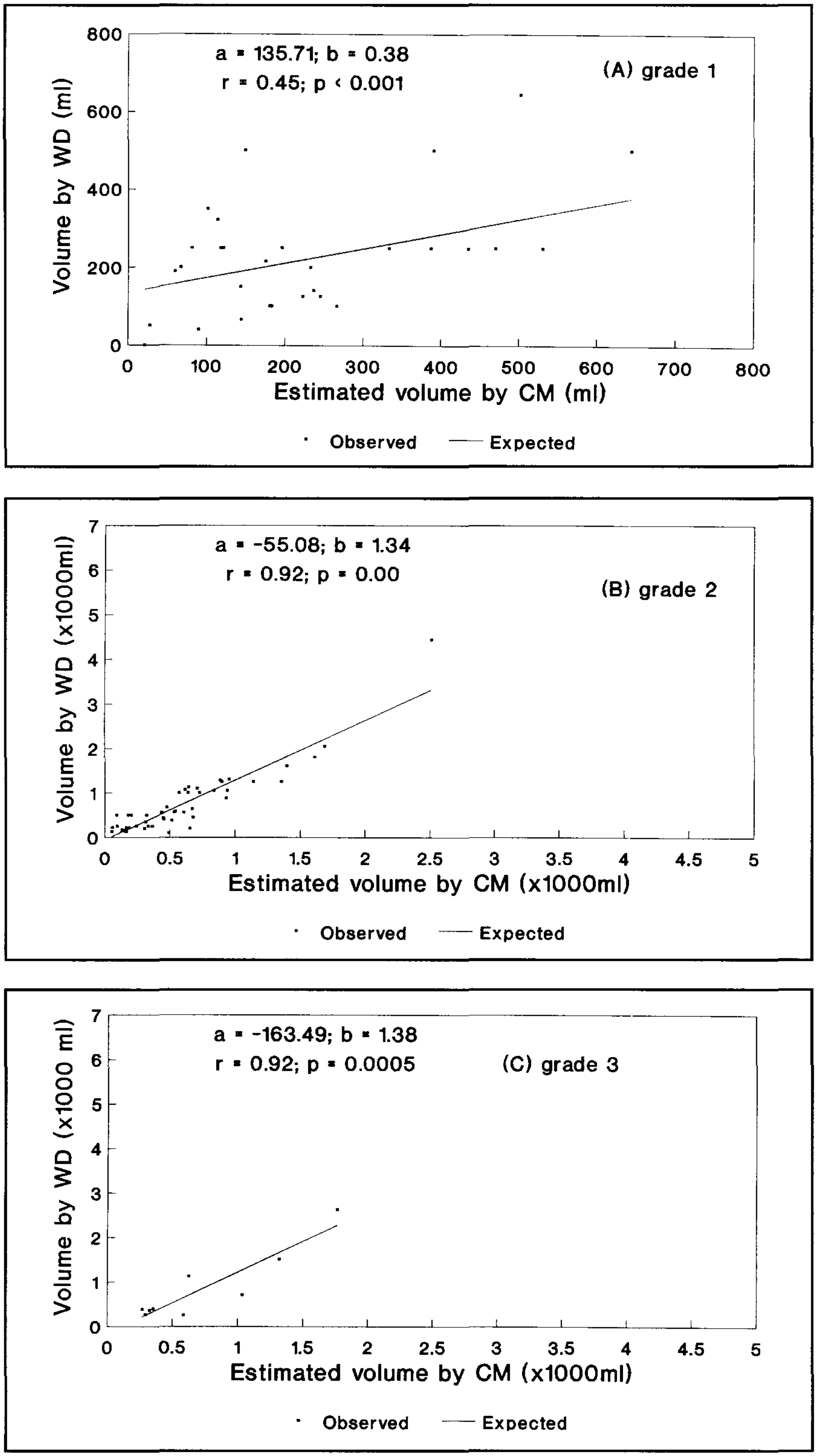

Fig. 4. Relationship between estimated edema volume by circumference measurement and edema volume by water displacement for three grades of edema (A, B & C).

not appropriate for patients with filariasis because the lymphedema usually involves the more distal parts of limbs.

Our results show that if properly done circumference measurements are adequate for determining changes in peripheral edema volume in patients with lower limb filarial lymphedema. The method is simple, does not require sophisticated equipment and can be used irrespective of skin condition. It is the most suitable for evaluating volume changes with different treatment strategies, particularly in a developing country like India. The technique is not only applicable to the outpatient or in-hospital environment, but also to the field situation since only a measuring tape is required. Trained health workers can readily use this technique. The current analysis did not consider upper limb filarial lymphedema since it is uncommon in this locality (accounting for only 1-2% of all lymphedema clinic patients). However, if properly done, the findings could be extrapolated to patients with edema of the arms. Circumference measurement has already been found applicable for monitoring change in edema volume after lymph nodal-venous surgery (12).

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