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COMMENTARY

ESTIMATING LIMB VOLUMES AND ALTERATIONS IN PERIPHERAL EDEMA FROM CIRCUMFERENCES MEASURED AT DIFFERENT INTERVALS

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Estimating limb volume and its alterations is vital for judging the success or failure of treatment for peripheral edema. There is no completely accurate method, apart from post-mortem amputation, of measuring the volume of the whole limb. Even water displacement only measures the distal part of a limb, usually omitting more central edematous soft tissue (1). All other methods only estimate the volume from circumferential measurements or from two diameters at right angles. However, one is seldom interested in the true volume of a limb, only in how it is altered during therapy, i.e., relative to its initial volume or to the (supposedly) 'normal' limb. For this purpose, good estimates are sufficient.

Limbs are often measured at 10 cm intervals (2). (For arms, 0 is usually taken as the tip of the middle finger; for legs 0 is usually taken as the heel with the distance to the mid-foot measurement given a minus sign.) Using the circumferences at these points, the volume is estimated as the sum of a series of truncated cones (1,3,4).

On the other hand, other systems are often employed, e.g., estimating the volume as a series of cylinders (5). It has been shown that estimations of edema using the truncated cones and the cylinders are almost identical (6). To simplify calculations when using cylinders to estimate the volume, Kuhnke suggests measuring at 4 cm intervals (5). Computers make this variation no longer necessary, but some still consider that more frequent measurements give much greater accuracy. It has been suggested, however, that there is likely to be so little difference between estimates at 10 and at 4 cm intervals that the latter may not be worth the extra effort (2,6) except at "problem sites" where additional measurements are needed because of grossly localized bulges of edema. Some measure only two circumferences: at the wrist (or ankle) and at the top of the limb. The volume is then estimated as a single truncated cone.

We recently encountered the problem of whether measurements made using 10 cm intervals gave similar results to those using the tapes supplied by Jobst (USA) with which measurements are made every 1.5 inches (3.81 cm). Because this interval distance is similar to (and less than 4 cm), it gave us an opportunity to test the above suggestion that shorter intervals than 10 cm are unnecessary.

A consecutive series of 15 patients (Grade 1 unilateral post-mastectomy arm lymphedema) were studied using both

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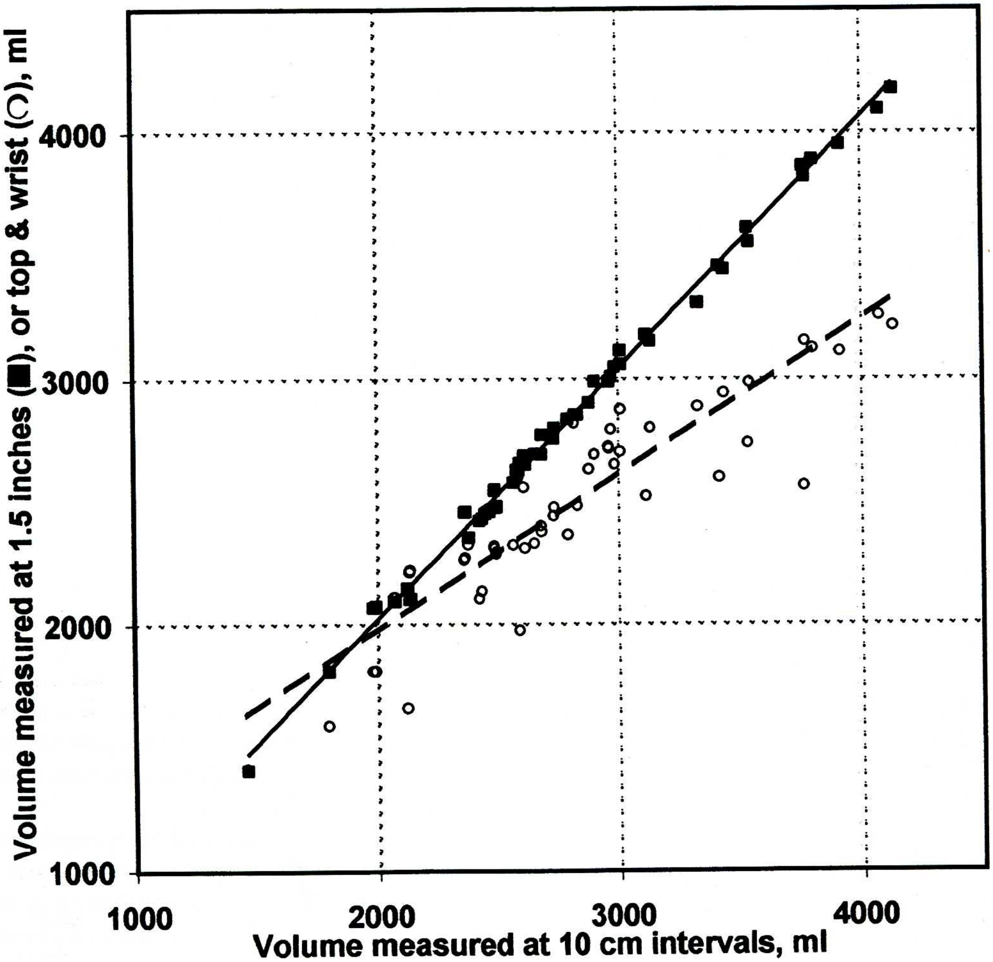

Fig. 1. Plotted estimates of volume (■) for both the initial and final volumes (n=60). Note how closely the 10 cm and 1.5 inch values coincide. At the larger volumes, the linear regression lines (——) are slightly above the intersection of the two sets of grid lines. However this difference, while significant, is of no practical clinical importance.

By contrast, when the estimates using only the top-and-wrist measurements are plotted (O), the values diverge considerably from those of the 10 cm values (and the 1.5 inch ones—not plotted). The linear regression line (— — —) lies far below the other because this measuring system neglects the bulges of the limb.

measuring systems (10 cm and 1.5 inches). Mean age was 60 (SD 11) years and the mean duration of lymphedema was 2.6 years (SD 3.9). Complex Physical Therapy (CPT), without benzopyrones, was used for 5 days for 4 weeks. Initial and final measurements of both lymphedematous and contralateral arms were used.

The 10 cm measurements were made as described. Jobst circumference measurements were taken at: -1.5, 0, 1.5, 3, 4.5, 6, 7.5, 9, 10.5, 12, 13.5, 15, 16.5 and 18 inches ('9' inches is placed at the elbow and '0' is approximately at the most distal portion of the wrist — using Jobst, USA, measurements sets). The top and the wrist measurements were also used

TABLE 1
Estimates of Volumes and of Alterations in Oedema Using 10 cm and 1.5 inch Intervals, and only the Top-and-Wrist

		10 cm intervals		1.5 inch intervals				Top-and-Wrist only			
	No.	Mean	S.E.	Mean	S.E.	Correl. Coef. with 10-cm[a]	Sig. of Dif. from 10 cm	Mean	S.E.	Correl. Coef. with 10-cm[b]	Sig. of Dif. from 10 cm
Volume of Lymphoedematous Arm (L, in ml)	30	3065	105.6	3112	106.4	0.998	10^{-8}	2611	75.0	0.89	10^{-9}
Volume of Normal Arm (N, in ml)	30	2442	73.4	2473	77.0	0.996	10^{-4}	2307	64.6	0.95	10^{-6}
Lymphoedema as % Normal=L/N	30	127%	4.2%	127%	4.2%	0.99	0.4	114%	2.4%	0.95	10^{-6}
Diff. in Lymphoedematous Arm=(Lt-Lo), in ml	15	-557	104.1	-571	102.1	0.998	0.06	-265	61.6	0.93	10^{-4}
Diff. in Lymphoedema as % Init. Vol. (Lt-Lo)/Lo	15	-15.7%	2.45%	-15.9%	2.36%	0.998	0.3	-9.2%	1.98%	0.91	10^{-5}
Diff. in Lymphoedema as % Norm=Lt/Nt-Lo/No	15	-24.2%	4.89%	-24.4%	4.70%	0.998	0.6	-12.1%	2.99%	0.95	10^{-4}
Change in Oedema={(Lt/Nt-1)-(Lo/No-1)}/(Lo/No-1)	15	-60.0%	3.62%	-60.3%	3.33%	0.94	0.9	-64.0%	7.51%	0.64	0.5

a. The significances of the Correlation Coefficients (from above down) are: 10^{-16}, 10^{-15}, 10^{-14}, 10^{-8}, 10^{-7}, 10^{-7}, 10^{-4}.
b. The significances of the Correlation Coefficients (from above down) are: 10^{-7}, 10^{-10}, 10^{-10}, 10^{-4}, 10^{-4}, 10^{-5}, 0.02.

separately. Volumes were estimated as truncated cones (1).

Table 1 shows the means and Standard Errors (SE) of the lymphedematous and normal volumes, the lymphedematous arm divided by the normal (n=30, initial and first combined), and the various ways of representing alterations in edema (n=15, final values), corresponding to equations 1, 2, 6 and 7 (see Ref. 1).

Whereas 10 cm intervals gave volumes which were statistically less than the 1.5 inch intervals, in fact these were actually only slightly less and the differences are of no clinical importance. This may also be seen from *Fig. 1*. The differences in volume before and after treatment were also less, but not significantly so. None of the results for the alterations of edema was significantly different between the two measurement intervals, findings that chiefly concern both therapist and patient.

The situation is considerably different if one used only the circumference at the top of the arm and that at the wrist to calculate the volume. The volumes, and the difference after treatment, were far less than those obtained by either of the other methods. The linear regression lines (*Fig. 1*) were: Volume (using 1.5 inch intervals) = Volume (using 10 cm intervals). 1.02 - 15.7 ml. Volume (using top & wrist only) = Volume (using 10 cm intervals). 0.64 + 706 ml. This discrepancy ($p = 10^{-18}$) occurs because top-and-wrist only method omits much of the intermediate bulges of the limb.

The results for the alterations of the edema also had notable (and clinically important) differences between 10 cm and the top-and-wrist measurements (to about half their values). The only exception was the Change in Oedema (eqn. 7 of Ref. 1), which gave comparable results (-64% vs. -60%). It is obviously far less satisfactory to use solely the top of the arm and the wrist. This conclusion has also been reached by others for the leg (7).

The essential similarity of the 10 cm and 1.5 inch methods are also shown by the very high and significant correlation coefficients for all seven estimates. (The significance of these were calculated using Fisher's z-transformation.) Except for the Change in Oedema, which is known to be far more affected by errors than the others (1), all were greater than 0.99. Even the low 95% Confidence Limits were greater than 0.99.

Again, apart from Change in Oedema, correlation coefficients of the 10 cm and the top-and-wrist methods were also high and very significant. Yet the significance of the differences between these two methods were also very great and of considerable clinical importance as were their regression lines. These findings illustrate the well-known fact that excellent correlations by no means imply identity. Systemic errors (neglecting the bulges of the limb) can still permit these while producing large differences in the absolute values. This is also found if non-edematous parts of limb are included, e.g., the thigh, when only the lower leg is edematous (1).

We conclude that the 10 cm and the 4 cm methods give very comparable results and are equally valid. Whereas shorter intervals improve accuracy, 10 cm ones are sufficient for clinical and scientific purposes; 4 cm ones are unnecessary. Nonetheless, just using two measurements for a whole limb should be avoided. These observations may not apply to extremely large limbs with numerous complex bulges and sulci (e.g., massive elephantine legs) and intervals of less than 10 cm should probably be used with grossly localized bulges.

This conclusion does not, however, signify that one can arbitrarily use 10 cm at one measurement time and 4 cm at another. Mixing them will undoubtedly cause errors. Moreover, the Jobst tape measuring system should be used when ordering low stretch elastic garments (as must individual systems of other manufacturers). Ten cm intervals are, however, sufficient for routine measurements of limb volume.

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