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VALIDITY AND INTRA- AND INTEROBSERVER RELIABILITY OF AN INDIRECT VOLUME MEASUREMENTS IN PATIENTS WITH UPPER EXTREMITY LYMPHEDEMA

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ABSTRACT

We investigated a method of indirect volume measurement that utilized surface measurements and a simplified formula derived from the formula for a frustum (Sitzia's method) to determine limb volumes in patients with breast cancer-related lymphedema of the upper extremity. Repeated measurements of upper-extremity limb volume were obtained by two observers on both upper extremities of 30 women with unilateral lymphedema. Volume was calculated using a simplified formula and compared with water displacement method as a gold standard. Indirect volume determination using Sitzia's method is comparable with the water displacement method, has comparable intra- and interobserver reliabilities, and can be used for diagnosis and follow up measurements of lymphedema. Indirect volume determination using surface measurements at 8 cm intervals is only suitable for follow up measurements. The methods should not be used interchangeably.

The incidence of breast cancer in The Netherlands is 100/100,000 woman per year (1). Lymphedema of the upper extremity is a common complication of breast cancer treatment. The reported prevalence of arm edema as a result of breast cancer treatment ranges from 6 to 43% (2). Lymphedema is an accumulation of lymph fluid in the limb resulting from an insufficiency of the lymphatic system (3). Quoted prevalence rates for lymphedema after breast cancer treatment vary (2). This variation in prevalence may be attributed to different assessment methods, levels of awareness of the problem and lack of a universally accepted definition of which degree of swelling defines "lymphedema" (2,4-7). Patients can develop an uncomfortable, unsightly and sometimes functionally impaired limb prone to repeated episodes of superficial infections (4-9).

As improved methods for the assessment and treatment of edema-related problems are developed, the need for reliable outcome indicators also increases (8). The volume of the upper extremity is measured directly, or indirectly calculated using measurements and a mathematical formula. The "gold standard" is defined as the volume determined by water displacement (10-12), although not all authors share this opinion. This method, however, has some disadvantages in that it is laborious and difficult to use in a clinical setting because of the difficulties in filling the volumeter and the risk of spilling water, and it gives no insight into which part of the upper extremity is swollen.

Besides the water displacement method (7,13-16), other indirect methods to assess lymphedema include circumference measurements (5,6,17), surface measurements (9,17), optoelectronic measurements (5,7,17), computer tomography (7,18) and magnetic resonance imaging (8).

Casley-Smith (19) has reported a very good correlation between simultaneous measurements of edema of the upper extremity by water displacement and by calculating volumes from circumferences. Nevertheless, intra- and interobserver reliability were not assessed. A similar study has been done for the lower extremities, but it used a population without edema (11). Karges et al concluded that calculated volume measurements, determined by summing segment volumes derived from truncated cone formula, were highly associated with measures based on water displacement but that the measures were not interchangeable (20). Sander et al found that, although volume of an edematous upper extremity calculated by geometric formulas correlated strongly with the volume determined by the water displacement, the measures obtained by the two methods did not agree (21). Similar results were found by Megens et al (22) in women at risk for edema following axillary lymph node dissection surgery for breast cancer.

Sitzia (9) describes a method (in this manuscript called: Sitzia's method) that uses surface circumference measurements (at 4 cm intervals) and a mathematical formula, derived from a formula for a frustum, to determine the volume of the upper extremity. This method is cheap, relatively easy, feasible, and hardly bothersome to the patient. Furthermore, volume can be calculated for different segments of the upper extremity and an indication can be given of the distribution of lymph fluid.

The aim of this study was to investigate the intra- and interobserver reliability as well as to compare volume determination using indirect volume determination (Sitzia's method) and water displacement method.

PATIENTS AND METHODS

The study group consisted of 30 patients 18 years and older (mean 56.4 ± 11.6 S.D.) with breast cancer treatment-related upper limb lymphedema (18 right and 12 left upper extremities). Exclusion criteria for this study were co-morbidity (such as serious kidney, heart- and lung disorders, skin damage/ infections in the upper extremities), recent operation on the upper extremity, the inability to elevate the upper extremity 90 degrees in the shoulder girdle, or the inability to extend the elbow. Signed consent was obtained from all volunteers in the study and the study was approved by the Medical Ethical committee of the University Hospital Groningen. Assessments were performed by two observers using a commercially available measuring apparatus which practitioners can easily acquire and are frequently used in daily clinical practice.

Circumference was measured on both arms at 4 cm intervals using a special designed tape measure was used with holes at every 4 cm. Using a surgical marking pen (standard line VX100, firma: Cory Bros), dots were made on both upper extremities. The first dot was on the styloid process of the radial bone. At each dot the circumference was determined using a Gulick Measuring Tape (model 258-J00305), by which the amount of tension during measurement can be standardized (*Fig. 1*). Furthermore, we compared the accuracy of the indirect method using circumference measurements at 8 cm intervals. The volume of the upper extremity is calculated (9) using the following formula described by Sitzia where c stands for the circumference of the arm every 4 or 8 cm. (L).

$$V = \frac{L}{4\pi}(c1c2 + c2c3 + c3c4 + \ldots\ldots + c13c14)$$

After obtaining these measurements, both upper extremities were independently immersed in a water displacement volumeter (Sammons-Preston, Model 258-F00605,

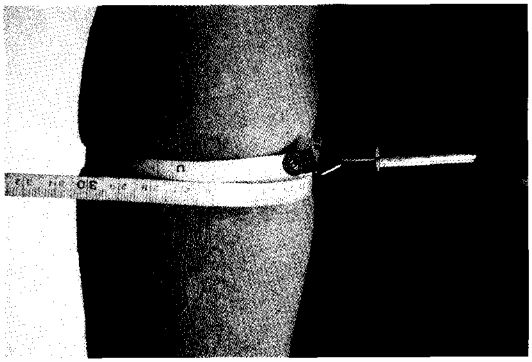

Fig. 1. Gulick Measuring Tape

7”x7”x30”), which was filled with water with a pleasant temperature of approximately 25°C. The water displaced by the hand (to the first dot on the styloid process) was collected separately. Then the arm was put into the volumeter until the front armpit line touched the edge of the volumeter. Care was taken to ensure the upper extremity was placed perpendicularly into the water and displaced. Water was collected in measuring cups with a 10 cc calibration. Both arms were patted dry at the end of the measuring session, and the dots were removed by means of stirilium disinfection lotion. The assessment was performed three times. The first and third measurements were performed by one observer and the second assessment by the second observer, hence intra- and interobserver variation could be determined. Observer sequence was determined randomly. Statistical analysis included the T-test (paired samples statistics) and intra-class correlation (one-way random) (SPSS 10.0).

RESULTS

Both the intra- and interobserver reliability of the water displacement method and Sitzia's method using surface measurements with 4 and 8 cm intervals showed no significant differences for both the affected and unaffected upper extremity *(Tables 1-3).*

Volume determination using Sitzia's method with 8 cm interval surface measurements in comparison with the water displacement measurements produced a significant difference [mean difference of 187 ml (± 380.4 S.D., p=0.01) for observer 1 and 193 ml (± 337 S.D., p<0.01) for observer 2 *(Table 4)*]. Four cm interval circumference measurements in comparison to the water displacement method showed no significant differences [mean difference of 31.6 ml (± 280.9 S.D., p=0.54) for observer 1 and 22.9 ml (± 297.5 S.D., p=0.68) for observer 2 *(Table 4)*].

Significant difference was found comparing the mean volume difference of the affected upper extremity using Sitzia's method with surface measurements at 4 cm intervals to those using 8 cm intervals [mean difference of 219.5 ml (± 206 ml S.D., p=<0.01) for observer 1 and 215.9 ml (± 217.2 S.D., p<0.01) for observer 2 *(Table 5)*].

DISCUSSION

Intra- and interobserver reliability of the water displacement method and Sitzia's method were both good. These results are comparable with the results of other researchers who have performed similar assessments (20-22). Further, a strong correlation (no significant difference) between Sitzia's method using surface measurements at 4 cm intervals and the water displacement method was found.

Although the intraobserver reliability showed no significant mean difference, the standard deviation of the mean difference was relative large in both the water displacement method and Sitzia's method. This especially applies to the results of observer 2 using Sitzia's method to calculate the volume with 8 cm interval surface measurements [affected arm: mean 59 ml (± 260.6 S.D.), unaffected arm: mean 124.8 ml (± 359.2 S.D.)]. In only one comparison, the intraclass correlation was not acceptable (0.62) *(Table 2).*

Segerström et al (23) has defined edema

TABLE 1
Intraobserver Reliability of the Water Displacement Method (15 Paired Observations). Volume Expressed in ml

	Mean 1 SD	Mean 2 SD	Mean difference SD	95% CI of mean difference	Sig. (2-tailed)	Intraclass correlation
Observer 1						
Affected arm	2563.3	2616	52.7	-111.2 to 5.9	0.07	0.98
	(535.9)	(555)	(105.7)			
Unaffected arm	2182	2236	54	-132.8 to 24.8	0.16	0.95
	(461.2)	(471.3)	(142.2)			
Observer 2						
Affected arm	2907.3	2896	11.3	-70.8 to 93.5	0.77	0.97
	(644.2)	(635.4)	(148.5)			
Unaffected arm	2362.3	2326.3	36	-45.2 to 117.2	0.36	0.96
	(547)	(509.4)	(146.6)			

Abbreviations: ml = milliliters; SD = standard deviation; CI = confidence interval; Sig = significance

TABLE 2
Intraobserver Reliability of Sitzia's Method. Surface Measurementsat 4 cm and 8 cm Intervals (15 Paired Observations). Volume Expressed in ml.

	Mean 1 SD	Mean 2 SD	Mean difference SD	95% CI of mean difference	Sig. (2-tailed)	Intraclass correlation
Observer 1						
4 cm intervals	2537.2	2551.1	13.9	-44.7 to 16.9	0.35	0.99
Affected arm	(453.5)	(475)	(55.6)			
4 cm intervals	2210	2232.2	22.2	-85.9 to 41.5	0.47	0.96
Unaffected arm	(400.4)	(448.8)	(115)			
8 cm intervals	2353	2362.2	9.2	-39.4 to 21	0.53	0.99
Affected arm	(442.3)	(459.6)	(54.5)			
8 cm intervals	2034.9	2067.4	23.6	-122.1 to 75.0	0.62	0.91
Unaffected arm	(396.6)	(441.5)	(177.9)			
Observer 2						
4 cm intervals	2925.1	2939.1	14	-113.9 to 85.9	0.77	0.96
Affected arm	(619.6)	(601)	(180.3)			
4 cm intervals	2374.9	2422.5	47.6	-159.3 to 64.1	0.38	0.9
Unaffected arm	(426.5)	(480.1)	(201.7)			
8 cm intervals	2723.7	2782.7	59	-203.3 to 85.3	0.40	0.92
Affected arm	(705.3)	(624)	(260.6)			
8 cm intervals	2130.9	2255.7	124.8	-323.7 to 74.1	0.20	0.62
Unaffected arm	(379)	(460.9)	(359.2)			

Abbreviations: ml = milliliters; SD = standard deviation; CI = confidence interval; Sig = significance

TABLE 3
Interobserver Reliability of the Water Displacement Method and Sitzia's Method, Using Surface Measurements at Intervals of 4 cm and 8 cm (30 Paired Observations). Volume Expressed in ml.

	Mean 1 (SD) Observer 1	Mean 2 (SD) Observer 2	Mean difference (SD)	95% CI of mean difference	Sig. (2-tailed)	Intraclass correlation
Water displacement Affected arm	2698.3 (606)	2749.6 (570.1)	51.3 (249.2)	-144.3 to 41.8	0.30	0.91
Water displacement Unaffected arm	2240.3 (470.6)	2268 (467.3)	45.7 (178.8)	-112.4 to 21.1	0.17	0.92
Sitzia's method (4 cm intervals) Affected arm	2729.9 (466.9)	2772.5 (553.9)	42.6 (259.5)	-138.4 to 53.2	0.37	0.88
Sitzia's method (4 cm intervals) Unaffected arm	2314.4 (391.4)	2330.2 (436.6)	15.9 (233)	-102.9 to 71.1	0.71	0.85
Sitzia's method (8 cm intervals) Affected arm	2510.4 (463.5)	2556.6 (613)	46.2 (404.9)	-197.4 to 104	0.54	0.73
Sitzia's method (8 cm intervals) Unaffected arm	2129.7 (399.7)	2105 (415.1)	24.6 (310.2)	-91.2 to 140.5	0.67	0.72

Abbreviations: ml = milliliters; SD = standard deviation; CI = confidence interval; Sig = significance

of the arm as a volume difference of 150 ml, and using this criteria, both methods are not accurate enough to assess this difference reliably. Water displacement and surface measurements are now the most used methods for upper extremity volume determination, and possibly this definition of arm edema may necessitate changing the volume difference to a higher limit. Noteworthy is the fact that volume determination using Sitzia's method with 4 cm interval measurements and the water displacement method are reasonably correlated.

If Sitzia's method using 4 cm and 8 cm interval surface measurements is compared to water displacement, a relatively large standard deviation in the mean difference is found *(Table 4)*, suggesting that the measures should not be used interchangeably, as has been concluded previously (20-22). Although volume determination using 8 cm interval has a poor correlation with the water displacement method *(Table 4)* and the interobserver reliability is poor *(Table 3)*, the intraobserver reliability is quite good (with the one exception mentioned). This could imply that follow up measurements using 8 cm interval surface measurements can be used, although the observers are not interchangeable. The latter method should gain some time in daily clinical practice.

In view of the large standard deviation in both the intraobserver reliability of observer 1 and 2 and the interobserver reliability it can be questioned if the water displacement method should be regarded as the "gold standard." The theoretical principles of the direct volume determination are without question correct but in practice it does not always allow precisely accurate measurements.

TABLE 4
Sitzia's Method, Using Surface Measurements at 4 cm and 8 cm Intervals, Versus Water Displacement Method (Affected Arm, 30 Paired Observations). Volume Expressed in ml.

	Mean 1 (SD) Sitzia's method	Mean 2 (SD) Water displacement	Mean difference (ml)	95% CI of mean difference	Sig. (2-tailed)	Intraclass correlation
4 cm intervals Observer 1	2729.9 (466.9)	2698.3 (606)	31.6 (280.9)	-73.3 to136.5	0.54	0.87
4 cm intervals Observer 2	2772.5 (553.9)	2749.6 (570.1)	22.9 (297.5)	-88.2 to 134	0.68	0.86
8 cm intervals Observer 1	2510.4 (463.5)	2698.3 (606)	187 (380.4)	-330 to -46	0.01	0.71
8 cm intervals Observer 2	2556.6 (613)	2749.6 (570.1)	193 (337)	-318.8 to –67.2	0.00	0.8

Abbreviations: ml = milliliters; SD = standard deviation; CI = confidence interval; Sig = significance

TABLE 5
Sitzia's Method, Using Surface Measurements at 4 cm Intervals, Versus Surface Measurements at 8 cm Intervals (Affected Arm, 15 Paired Observations). Volume Expressed in ml

	Mean 1 (SD) 4 cm intervals	Mean 2 (SD) 8 cm intervals	Mean difference (SD)	95% CI of mean difference	Sig. (2-tailed)	Intraclass correlation
Observer 1	2729.9 (466.9)	2510.4 (463.5)	219.5 (206)	142.6 to 296.4	0.00	0.8
Observer 2	2772.5 (553.9)	2556.6 (613)	215.9 (217.2)	134.8 to 297	0.00	0.92

Abbreviations: ml = milliliters; SD = standard deviation; CI = confidence interval; Sig = significance

Though upper extremity volume determination using the indirect volume determination with circumference intervals of 4 cm can be performed reasonably fast and easily, a drawback of this method is that the volume of the hand cannot be determined by this method. Because many patients with edema of the upper extremity have impairments due to the fact that they have hand edema, determination of the hand volume should be done using the water displacement method.

In conclusion regarding clinical implications: indirect volume determination using surface measurements with 4 cm intervals with a formula for a frustum (Sitzia's method) is comparable with the water displacement method ("the gold standard"), with comparable intra- and interobserver reliabilities. Sitzia's method can be used in diagnosis and follow up measurements of lymphedema. Indirect volume measurements using surface measurements with 8 cm intervals are only suitable for follow up measurements, and the methods should not be used interchangeably.

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