Quantitative comparison between the laser scanner three-dimensional method and the circumferential method for evaluation of arm volume in patients with lymphedema

Nicola Cau, PhD,[a] Manuela Galli, PhD,[a,b] Veronica Cimolin, PhD,[a] Alida Grossi,[c] Ivan Battarin,[a] Greta Puleo,[a] Augusta Balzarini, MD,[c] *and* Augusto Caraceni, MD,[c] *Milan and Rome, Italy*

ABSTRACT

Objective: Several methods are used to evaluate arm volumes. The most commonly used methods are water displacement and the circumferential method (CM), but these techniques have some limitation in application in clinical settings and accuracy. Recently, the laser scanner three-dimensional (LS3D) method was successfully proposed as a valid method for volume measurements of the upper limb in healthy individuals. The aim of the study was to compare, in terms of intraobserver and interobserver reliability, the CM and LS3D method to measure the upper limb in a group of women with upper limb lymphedema.

Methods: There were 200 women with upper limb lymphedema (mean age, 64 ± 9 years; body mass index, 24.72 ± 2.94 kg/m^2) involved in this study. Arm measurements were obtained with both the CM and LS3D method. Statistical analysis was conducted to compare the CM and LS3D method.

Results: Both the CM and LS3D method have a satisfactory level of agreement, but we found some statistically significant differences in terms of some measurements (both circumferential and volume measurements).

Conclusions: The data obtained in this study indicate that the LS3D method could represent a reliable, valid method to measure arm circumferences and volumes in arms with lymphedema, suitable for daily clinical use. It combines precision, reproducibility, and ease of use with the possibility of measuring geometric parameters and shape information of scanned limbs. (J Vasc Surg: Venous and Lym Dis 2018;6:96-103.)

Lymphedema is a condition of localized fluid retention and tissue swelling caused by a compromised lymphatic system, which normally returns interstitial fluid to the thoracic duct, then the bloodstream. The condition can be inherited or can be caused by a birth defect, although it is frequently caused by cancer treatments and by parasitic infections. In particular, arm lymphedema is a potential side effect of breast cancer surgery and radiation therapy that can appear in some people during the months or even years after treatment ends. It is characterized by swelling in the upper quadrant on the ipsilateral side of the operation or irradiation. The reported incidence of this type of lymphedema varies according to the degree of swelling that is used to define clinically significant lymphedema, as does the method of measurement to quantify arm volume.[1] However, a systematic review of 72 studies concluded that it affects approximately one in every five women treated for breast cancer.[2]

Arm lymphedema needs to be measured quantitatively to aid in the assessment of severity at the time of diagnosis and remeasured to assess response to treatments that may be administered. Furthermore, accurate measurement of arm volume is needed in observational studies of arm lymphedema as a complication of local treatment for breast cancer and in research trials of prevention or treatment. Evaluation of the effectiveness of treatments for lymphedema requires an accurate, easy-to-use method for the calculation of arm volume. Nowadays, there are several methods to evaluate arm volumes. The most commonly used methods are water displacement (WD) and the circumferential method (CM). CM represents the most common method in clinical application[3-5]; it is widely used because of its limited cost, but the estimation of arm volume is subject to several potential errors. The formula used for the volume calculation based on circumferential measures presumes that the arm is approximated to a truncated cone, neglecting the swelling typical of the edematous arm. The lack of accuracy is added to the inability to measure the arm's protuberant shape and swelling. WD represents the "gold standard"[6-8] and is a reliable method of measuring limb volume.

Several studies compared these two techniques in terms of accuracy and reliability,[5,7-13] demonstrating that volumes are most accurately measured by

From the Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan[a]; the IRCCS "San Raffaele Pisana," Tosinvest Sanità, Rome[b]; and the Department of Palliative Care, Pain Therapy and Rehabilitation, IRCCS Fondazione Istituto Nazionale dei Tumori, Milan.[c]

This work was supported by Polisocial Award 2012/2013, Politecnico di Milano.

Author conflict of interest: none.

Correspondence: Nicola Cau, PhD, Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, p.za Leonardo da Vinci 32, Milano 20133, Italy (e-mail: nicola.cau@gmail.com).

The editors and reviewers of this article have no relevant financial relationships to disclose per the Journal policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

2213-333X

https://doi.org/10.1016/j.jvsv.2017.08.014

WD.[12,14,15] However, although it is considered the gold standard,[6-8] many researchers choose not to use the WD method because it is time-consuming, is not portable, presents water spillage and space need,[10,16] and can be unhygienic.[15,17] Considering the difficulties related to the WD method, especially for routine clinical use, the search for alternative methods of volume determination remains a worthwhile pursuit. A precise measurement of lymphedema volume is in fact mandatory to determine the effect of therapies and treatments as well as to quantify the pathologic impairment.

The laser scanner three-dimensional (LS3D) method was successfully proposed recently as a valid method for volume measurements. The LS3D method is generally applied in orthopedics, in design of orthoses and other health and well-being applications. It has the advantages of being relatively inexpensive, fast, accurate, and noninvasive, and it has no contact with the patient.[18] The LS3D method has been studied in terms of accuracy and reproducibility and compared with the gold standard. McKinnon et al[19] compared WD and digital laser scanning in a series of inanimate objects of known and unknown volume. A similar comparison was made in measuring the volume of upper limbs of 10 healthy volunteers. McKinnon demonstrated that laser scanning has similar accuracy and superior reproducibility compared with the WD method. In our previous work, we compared, in terms of intraobserver and interobserver reliability, the CM and LS3D method for upper limb measurement in a group of healthy subjects.[20] We concluded that the LS3D method could be an innovative and valid method of measuring the upper limb volume that could be used instead of CM.

From these considerations, the aim of this study was a comparison between the circumferential measurements—in general performed in clinical routine—and those obtained with an LS3D system in a large group of subjects with upper limb lymphedema related to breast cancer treatments.

ARTICLE HIGHLIGHTS

- **Type of Research:** Prospective cohort study
- **Take Home Message:** Bilateral arm volumes of 200 women with unilateral lymphedema were assessed to compare segmental circumference measurements with three-dimensional laser measurements. There seemed to be good correlation between the two methods, with a good level of agreement for both arms of the patients.
- **Recommendation:** The authors found the three-dimensional laser volume measurement technique a good alternative to segmental circumference tape measurements to assess the volume of the limb with lymphedema and to compare it with the volume of the normal arm.

METHODS

There were 200 women with upper limb lymphedema (mean age, 64 ± 9 years; mean weight, 64.27 ± 9.58 kg; mean height, 161.05 ± 5.89 cm; and mean body mass index, 24.72 ± 2.94 kg/m^2) involved in this study. Patients with unilateral lymphedema of the upper limb (after quadrantectomy or mastectomy with axillary dissection for breast cancer) were enrolled. On the contrary, the exclusion criterion was the presence of bilateral lymphedema. The inclusion criterion of unilateral lymphedema was introduced to make possible the comparison of the lymphedema's severity with the patient's healthy condition, which is assumed to be the contralateral limb.

Participants were recruited from the Palliative Care, Pain Therapy, and Rehabilitation Department, IRCCS Fondazione Istituto Nazionale dei Tumori, Milano, Italy. They were all adult women who gave written informed consent.

Similar to the study conducted by Cau et al, both arms of each participant were measured by the CM and LS3D method. The measurements were performed by expert operators who had previous experience with arm measurements in patients with lymphedema and who also received special training for the study, especially in measurement by the LS3D method. The study was approved by the Ethics Committee of the institute; written informed consent of the patients was obtained.

CM measurements. The upper limb circumferences were measured with a normal tape measure (1-mm sensibility). The participants were in standing position, with arms stretched at the shoulder level with the palm of the hand down. Measurements were made corresponding to marks made on the skin using a dermatologic pen from the ulnar styloid process of the wrist to 20 cm proximal to the lateral epicondyle (corresponding to the inferior extremity of the deltoid muscle) with 4-cm intervals. To uniquely define the arm and the upper arm, one additional point was detected corresponding to the olecranon, indicated as the middle point. To not influence the operator, all marked points were deleted from the skin surface after each measurement.

The numbers of measured points depend on the length of arm. A variable number between 9 and 10 points was considered. A general representation of the measured points is shown in Fig 1.

The arm volume was calculated by the frustum formula[21]:

$$\text{Volume} = \sum \frac{\left(x_{(i+1)}{}^2 + x_i{}^2 + x_i . x_{(i+1)}\right)}{3\pi}$$

where $x_{(i+1)}$ and x_i are the circumferences corresponding