# The Reliability and Concurrent Validity of the Figure-of-Eight Method of Measuring Hand Edema in Patients with Burns

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**Objective: Water volumetry is considered the "gold standard" for hand edema assessment. This technique requires considerable time, staff, and specialized equipment. The figure-of-eight method for hand edema assessment has been tested only in the orthopedic population. The objective of this study was to test the reliability and concurrent validity of the figure-of-eight method of measuring hand edema in the burn patient population. Methods: We conducted a prospective blinded study with 20 burned patients (33 edematous hands) admitted from February to May 2005. Two testers performed three separate blinded measurements on each edematous hand, using the figure-of-eight technique. A third tester performed two measurements, using water volumetry. An independent investigator recorded all measurements. Intratester and intertester reliability were analyzed. Concurrent validity was examined and compared with water volumetry measurements. Results: Intraclass correlation coefficients (ICC) for the intratester reliability of the figure-of-eight method were 0.96 for tester 1 and 0.97 for tester 2. The ICC for intertester reliability of the figure-of-eight measurements was 0.94. The intratester ICC for volumetric measurements was 0.99. Correlation coefficient (Pearson's) for tester 1 was 0.83 ($P < .01$), and for tester 2, 0.89 ($P < .01$). Conclusion: The figure-of-eight technique is a reliable and valid measurement tool for measuring hand edema. This technique is a more clinically feasible tool than water volumetry in the burn patient population. (J Burn Care Res 2007;28:157–162)**

Measuring edema is an important part of the physical examination of individuals with burns, particularly those affecting the hands. Hands are commonly affected by edema and present a particularly troublesome aspect for rehabilitation. To improve outcomes in this area, clinicians require a method of taking these measurements that is reliable, valid, cost-effective and time-efficient.[1]

Volumetry, a measurement based on the principle of water displacement as a measure of volume, is considered the "gold standard" for measuring hand size.[2] The volumeter is a standardized tool that allows the therapist to measure hand edema.[1] Reliability and validity of volumetric measurements is well established.[2,3] Waylett-Rendall and Seibly[3] measured hand size of a rubber model of a hand, individuals with edema, and individuals without edema utilizing volumetry. They reported measurement accuracy within 1% of the total volume. Despite the well-documented reliability and validity of volumetric measurements, volumetry has several limitations.[4] This method is time-consuming and requires expensive specialized equipment. The volumetric measurement requires consistent water temperature, a level surface, and a consistent hand position for each time of measurement.[2,3,5,6] For these reasons volumetry is difficult to utilize in an intensive care unit (ICU) setting.

The figure-of-eight technique for measuring hand edema offers an alternative that is both reliable and valid.[7–9] Three recent studies have documented that the figure-of-eight method may be an alternative to volumetry for measuring hand edema.[7–9] The figure-of-eight measurement technique has been established as a useful

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clinical tool in an orthopedic patient population;[7] however, its usefulness has not been tested in other patient populations. The purpose of our study was to determine the reliability and concurrent validity of the figure-of-eight method for measuring hand edema in patients with burns. Volumetry was used as the criterion measure to establish concurrent validity.

## METHODS

The protocol for this study was approved by the Institutional Review Board of Brooke Army Medical Center. Twenty subjects (33 hands) between 21 and 79 years of age (mean age, 36.6 years) participated after providing informed consent. Nineteen of the participants were right hand dominant and one was left hand dominant. All subjects had burns affecting hand edema, 13 with bilateral involvement. The burns ranged from 1% to 29% TBSA, with the average TBSA 12% (Table 1). Patients were excluded from the study if they were unable to safely place the edematous hand in the water volumetry test position, were unable to tolerate immersion into room temperature water, or lacked the required bony landmarks needed for figure-of-eight measurement because of amputation or surgery. Testers took figure-of-eight and volumetric measurements of 33 hands.

A laminated tape measure was used to take figure-of-eight measurements of the hand. The tape measure was marked in metric units on one side and was blank on the other side. The blank side was face up during measurements for blinding. A hand volumeter set (Richardson Products, Frankfort, IL) was used for volumetric measurements. The set consisted of a hand volumeter, a plastic beaker to catch the displaced water, and two 500-ml graduated cylinders with 5-ml increments to measure the amount of water displaced.

The testers and data recorder were licensed occupational or physical therapists. Tester 1 and tester 2 performed blinded figure-of-eight measurements. Tester 3 obtained volumetric measurements. A fourth investigator served as a data recorder for each tester. Two practice sessions measuring a hand without edema were completed on separate days and included discussion regarding the most effective way to standardize the procedure. None of the subjects participated in the practice sessions. All jewelry was removed prior to data collection. All dressings were removed prior to measurements and any excessive wound drainage was wiped clean. Tester 1 and tester 2 took three consecutive figure-of-eight measurements first. The order of the testers was randomized. The subject's involved extremity was placed in forearm pronation with the wrist in neutral flexion, extension, and radial and ulnar deviation. The fingers rested in adduction throughout the measurement process. Tester 1 and 2 performed the figure-of-eight measurement on each subject's hand in the following manner, with the blank side of the tape measure facing upward: 1) The starting point for the tape measure was the distal aspect of the ulnar head on the dorsal surface. 2) The tape measure was placed across the volar surface of the wrist just distal to the radial styloid. 3) The tape measure was positioned diagonally across the dorsal aspect of the hand, with the distal edge of the tape measure aligned over the fifth metacarpophalangeal (MCP) joint line. 4) The tape measure was then positioned over the palmar surface of the hand, with the distal edge of the tape touching the MCP joint flexion crease of the index and small finger. 5) The tape measure continued around the second metacarpal head and was placed diagonally across the dorsum of the hand back to the starting point. The endpoint was marked with a grease pen at the intersection of the distal edge of the starting point and the end of the tape measure. 6) The tester then removed the tape measure from the patient's hand and handed it to the data recorder. The recorder documented the measurement, wiped the mark clean, and returned the measuring tape back to the tester. This process was repeated until all testers had completed their figure-of-eight measurements (Figure 1). For study purposes the laminated tape measure was disinfected with Wex-cide-128® (Wexford Labs, Kirkwood, MO) between patients; however, a disposable tape measure is recommended for clinical use.

Tester 3 took two volumetric measurements using the method described by Schultz-Johnson,[2] Waylett-Rendall and Seibly,[3] and King.[6] The volumeter was filled with water until water began to overflow into a beaker placed below the spout. The water temperature was measured by Tester 3 and recorded by the data collector. Once water stopped flowing, the beaker was removed, emptied, and wiped clean. The participant's hand was then placed into the volumeter with forearm pronated, fingers adducted, and thumb

**Table 1.** Demographic characteristics

| Characteristic | Value |
|---|---|
| Age | 36.6 yrs (Range, 21–79) |
| Gender | 20 Males/0 Females |
| Hand dominance | 19 Right/1 Left |
| TBSA of burn | 12% (Range, 1–29) |
| Hand involvement | 7 Unilateral/13 Bilateral |

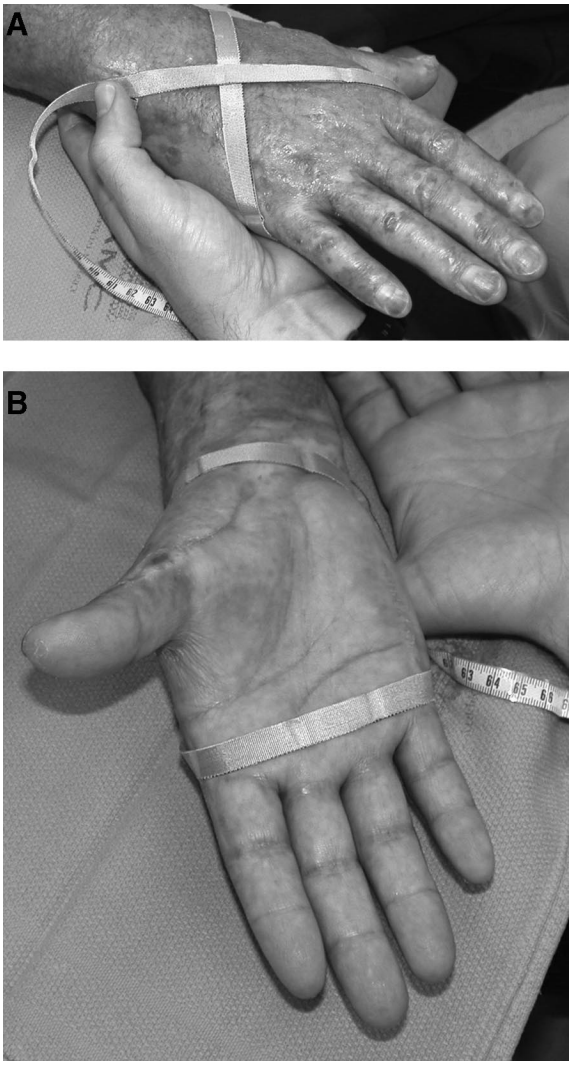


**Figure 1.** Figure-of-eight technique.

facing the spout (Figure 2). The participant's hand was lowered slowly into the volumeter until the web of the middle and ring finger rested on the stop dowel. Displaced water was collected in the beaker below the spout. The participant's hand was removed from the volumeter once all water stopped flowing from the overflow spout. Tester 3 poured the displaced water from the beaker to the graduated cylinder to measure the amount of water displaced by placing himself at eye level with the water line. If more than 500 ml of water was displaced, then a second graduated cylinder was used. The data recorder entered the measurement into the data collection spreadsheet. This process was repeated to complete two measurements for each hand. Whenever possible, this measurement was taken with the patient standing. Seven of the 20 subjects who were intubated or sedated and unable to stand were adequately supported by staff, including a respiratory therapist, during the entire volumetric measurement process. The patient's upper-extremity position was maintained by staff members to include forearm pronation, finger adduction, and thumb facing the spout. The temperature of the water was 76°–84° F for all participants.

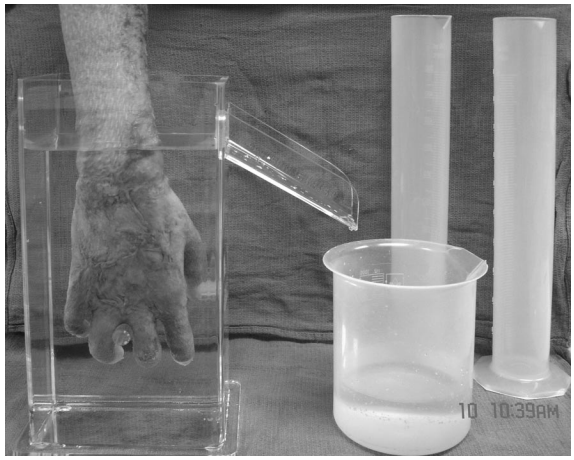

**Figure 2.** Volumetry set-up.

Statistical analyses were conducted with SPSS for Windows (version 12.0, SPSS, Chicago). Descriptive statistics were calculated for measurements taken by each tester. Intraclass correlation coefficient (ICC) and standard error of measurement (SEM) were used to determine intratester and intertester reliability of the figure-of-eight measurements, as well as intratester reliability of the volumetric measurements.[10] $ICC_{3,1}$ was used to examine intratester reliability. The three measurements taken by each of the figure-of-eight testers and the two measurements taken by the volumetry tester were used to calculate separate intratester ICCs for each tester. $ICC_{2,3}$ was used to examine intertester reliability. The mean of the three measurements of each figure-of-eight tester were used to calculate the intertester ICC.[10] SEM was calculated as $SEM = SD \times (1 - ICC)^{1/2}$, where SD is the standard deviation of the measurements and ICC is the reliability coefficient for that measurement. The Pearson's product moment correlation coefficient ($r$) was used to examine the relationship between figure-of-eight and volumetric measures as an indicator of concurrent validity. Significance level was set at $P < .05$.[10]

## RESULTS

Descriptive statistics for the figure-of-eight and volumetric measurements are presented in Tables 2, 3,

**Table 2.** Descriptive statistics for the figure-of-eight (cm) and volumetric (ml) measurements of 33 hands

| Measurement | Mean | Range | SD |
|---|---|---|---|
| Figure-of-eight, tester 1 | | | |
| First measurement | 49.4 | 45.0–54.0 | 2.3 |
| Second measurement | 49.3 | 45.0–53.5 | 2.4 |
| Third measurement | 49.2 | 44.7–54.0 | 2.4 |
| Figure-of-eight, tester 2 | | | |
| First measurement | 49.7 | 44.7–53.9 | 2.4 |
| Second measurement | 49.7 | 45.0–54.0 | 2.3 |
| Third measurement | 49.5 | 44.7–53.4 | 2.4 |
| Volumetry, tester 3 | | | |
| First measurement | 614.4 | 470.0–710.0 | 67.2 |
| Second measurement | 617.6 | 475.0–730.0 | 67.7 |

and 4. ICCs for the intratester reliability of the figure-of-eight method were 0.96 (SEM, 0.47 cm) for tester 1 and 0.97 (SEM, 0.41 cm) for tester 2. The ICC for intertester reliability of the figure-of-eight measurements was 0.94 (SEM, 0.58 cm) (Figure 3). The intratester ICC for volumetric measurements was 0.99 (SEM, 7.70 ml). Pearson's *r* for the mean of the three figure-of-eight measurements taken by tester 1 and the mean of the two volumetric measurements was 0.83 ($P < .01$). Pearson's *r* for the mean of the three figure-of-eight measurements taken by tester 2 and the mean of the two volumetric measurements was 0.89 ($P < .01$). Pearson's *r* for the first figure-of-eight measurement for rater 1 and the first volumetric measurement was 0.85 ($P < .01$). Pearson's *r* for the first figure-of-eight measurement for rater 2 and the first volumetric measurement was 0.90 ($P < .01$).

## DISCUSSION

Pellecchia[8] and Maihafer et al[9] demonstrated two similar techniques with different anatomical landmarks that went across the dorsum of the hand to measure hand volume in the noninjured population. Because the majority of return blood flow takes place on the dorsal surface of the hand through lymphatic and venous systems,[5,11] Maihafer et al[9] reasoned that the tape measure should cross the dorsal surface of the hand rather than the palmar surface. Maihafer et al[9] argued that the figure-of-eight method measures volume in the hand more effectively than single-joint circumferential measurement. Leard et al[7] demonstrated reliability and concurrent validity of the figure-of-eight technique in individuals with orthopedic conditions affecting the hand, using a similar technique. Pellecchia[8] reported high intertester and intratester reliability, with ICC of 0.97 and 0.99, respectively. Maihafer et al[9] reported ICC of 0.99 for both intertester and intratester reliability. Leard et al[7] reported ICC of 0.99 for intertester reliability and 0.98 or greater for intratester reliability. All three studies yielded Pearson product moment correlation coefficients between volumetric and figure-of-eight measurements greater than or equal to 0.93, and the investigators interpreted these findings as indicative of high concurrent validity in the nonpatient population or in patients with orthopedic injuries.

**Table 3.** Results: intratester reliability

| Tester | ICC | SEM |
|---|---|---|
| 1 | .96 | .47 cm |
| 2 | .97 | .41 cm |
| 3 | .99 | 7.70 ml |

(ICC = intraclass correlation coefficient; SEM = standard error of measurement).

**Table 4.** Results: concurrent validity ($\alpha = 0.05$)

| Comparison | *r* Value | *P* Value |
|---|---|---|
| Rater 1 vs Rater 3 | 0.83 | <.01 |
| Rater 2 vs Rater 3 | 0.89 | <.01 |

In our study, results for burned patients with hand edema were similar to those shown previously for orthopedic patients. According to Munro,[12] the strength of the correlation coefficients obtained for both intertester and intratester reliability is classified as very high. Portney and Watkins[10] state that the reliability correlation must exceed 0.90 to ensure valid clinical measurements and that any value exceeding 0.75 indicates good correlation. Our measurements meet these specifications. Additionally, the high intertester reliability demonstrated in this study suggests that, utilizing the figure-of-eight technique, different therapists can accurately assess hand edema on the same patient, perhaps on different days or at different times, and gather meaningful information. In this study the SEM for intertester reliability was 0.58 cm. Approximately 95% of the time the actual value of hand size should be within ±1.16 cm of the measured value.[10] Therefore, measurements must change by 1.16 cm to be considered reflective of an actual difference in hand size and to represent a clinically meaningful change.

Volumetric measurements are conventionally used to quantify hand size; therefore, volumetry was selected as the criterion measure to examine concurrent

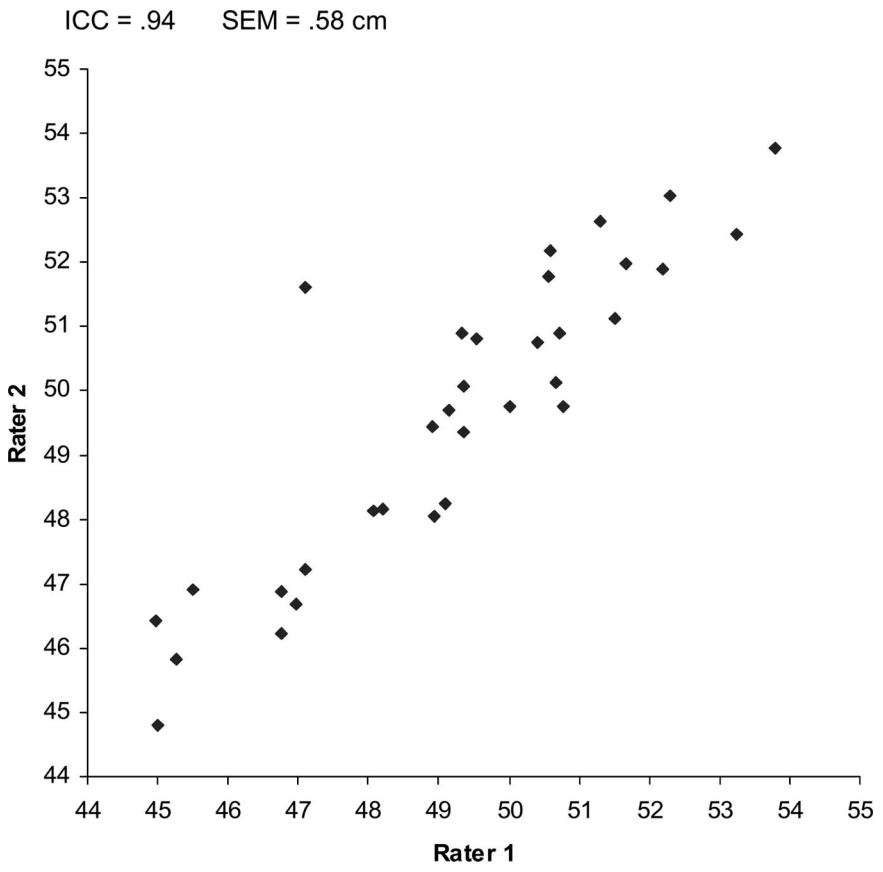


**Figure 3.** Intertester reliability correlation graph.

validity of the figure-of-eight technique. Correlational analysis with the mean values of volumetric and figure-of-eight methods demonstrated high concurrent validity. High concurrent validity was also shown in an analysis of the first trial of each method for measuring hand edema. This finding, in concert with high intratester reliability, demonstrates that accurate information about a patient's hand size can be obtained with a single measurement by means of the figure-of-eight technique described here.

This study illustrates that the figure-of-eight technique is a reliable and valid measurement tool that can be utilized for severely edematous hands, commonly seen in the burn patient population. It is important to note that the standard deviation for the figure-of-eight and volumetric measurements was not higher than in recent studies, despite a significantly greater hand size (Table 5). The landmarks utilized with the figure-of-eight technique were still easily palpated with the presence of edema associated with burn injury and fluid resuscitation. This technique does not require expensive specialized equipment and can be performed in a variety of clinical settings (Table 6). There are several advantages to using the figure-of-eight technique in an intensive care setting instead of volumetry. These include eliminating the risk of dislodging an endotracheal tube, decreasing staff requirements, and timely edema assessments. The figure-of-eight technique can also be utilized when volumetry is contraindicated, such as cases involving early postoperative skin grafts, open wounds, and the presence of k-wires. Last, we have shown that it is

**Table 5.** Comparison of studies

| Study | Volume: Mean/SD | Figure-of-Eight: Mean/SD |
|---|---|---|
| USAISR (burn patients) | 616 ml/67.43 | 49.4 cm/2.36 |
| Pellechia[8] (nonpatient) | 427 ml/74.7 | 41.7 cm/2.93 |
| Leard et al[7] (hand patients) | 515 ml/86.45 | 45.6 cm/2.85 |

**Table 6.** Comparison of methods

| Variable | Volumetry | Figure-of-Eight |
|---|---|---|
| Equipment required | Hand volumetry kit | Tape measure |
| Cost of equipment[13] | $219.00 | $9.00 |
| Time to perform | 10–30 min with setup | 1 min |
| Setting conditions[5] | Level surface and Room-temperature water | None |

reliable between testers and therefore can be used to track changes in hand volume in response to treatment modalities; thus, the effectiveness of treatment can be monitored with an easy technique.

## CONCLUSION

The figure-of-eight technique is a practical measurement tool and can be performed rapidly. We have shown it to be both reliable and valid, and it can be a valuable alternative to volumetry in the burn patient population. In future studies this proven tool will help to determine best clinical practices for edema management. The figure-of-eight technique can be used in burn patients to examine the efficacy of edema management techniques such as elevation, edema mobilization, and high voltage electrotherapy and products such as Coban® (3M, St. Paul, MN) and edema gloves. This technique can also be utilized in studies to assess function at different levels of edema.

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