

Original Article

# Reliability of a new practical evaluation method for pitting edema based on the depth of the surface imprint

HARUKI KOGO, MS<sup>1, 2)\*</sup>, TOSHIO HIGASHI<sup>2)</sup>, JUN MURATA<sup>2)</sup>

<sup>1)</sup> Faculty of Rehabilitation Science, Nishikyushu University: 4490-9 Ozaki, Kanzaki-machi, Kanzaki-shi, Saga 842-0815, Japan

<sup>2)</sup> Department of Health Science, Graduate School of Biomedical Sciences, Nagasaki University, Japan

**Abstract.** [Purpose] To develop and verify the reliability of a new practical evaluation method for pitting edema, which uses the depth of the surface imprint as an indicator. [Subjects] We included 26 inpatients (52 legs). [Methods] The subjects were diagnosed with edema, and we verified the inter- and intra-rater reliabilities of the edema gauge using intraclass correlation coefficients. [Results] For the first and second measurement values and the measured values between the examiners, the intraclass correlation coefficients were high. [Conclusion] Therefore, our findings suggest that the edema gauge, which measures the depth of the surface imprint, has sufficient intra- and inter-rater reliabilities.

**Key words:** Depth of the surface imprint, Practical evaluation, Edema

(This article was submitted Jan. 13, 2015, and was accepted Feb. 14, 2015)

## INTRODUCTION

Diseases with symptoms of edema that are encountered at medical institutions vary from internal diseases (e.g., kidney, liver, heart, and endocrine diseases) to orthopedic diseases, central nerve disease, and malignant tumors. Generally, edema exceeds a physiological compensatory function to an interstitial fluid and is defined as the condition in which superfluous water content is gathered<sup>1)</sup>. Its pathogeny includes situations in which the water provision system of the interstitial fluid becomes superfluous; thus, the edema exceeds the power of the physiological water content redistribution, water content redistribution system of the interstitial fluid does not function sufficiently, and tissue fluids are not sufficiently collected<sup>1)</sup>. An edema is categorized as either pitting edema<sup>2)</sup> or non-pitting edema. Identification of pitting edema is possible by using acupressure on the superficial skin. The origins of pitting edema include a reduction of the oncotic pressure by hypoalbuminemia, a rise in the plasma hydrostatic pressure, and hyperpermeability of the capillaries. Conversely, the origin of non-pitting edema is reflux difficulty in a lymph and mucopolysaccharide, which causes docking deposition of protein in the stromata<sup>3)</sup>. Edema of the extremities is a somatic symptom that is also observed in daily life situations.

Although pitting edema is generally identified through questions, a physical examination, and palpation, it is difficult to evaluate the condition of an edema quantitatively. Although palpation is the most convenient method, palpation is semi-quantitative and lacks reproducibility of a measured value. In addition, circumferential measurement is performed<sup>4-7)</sup>, and the error of a measurement region is directly reflected in the error of a measured value; and furthermore unification of a measured region is not prudent. Moreover, performing laterality (measuring both sides) and variation (measuring twice) is meaningful because one alone measurement cannot quantitatively evaluate an edema. Other methods include water bath draining<sup>3, 8, 9)</sup>, echography, computed tomography (CT), magnetic resonance image (MRI), and lymph scintigraphy<sup>10)</sup>, among other. Recently, the impedance method<sup>11)</sup> has been performed in the fields of obstetrics and gynecology<sup>12)</sup>. However, this evaluation method is a physical and economic burden to the patient because it requires a high-priced instrument and is not easy to perform. Therefore, the development of a novel objective evaluation method that can easily determine the condition of an edema is warranted.

For the reasons, conventional assessment methods are not practical and do not allow for quantitative evaluation. Therefore, it is considered the status-quo that evaluation of an edema is not performed. In the case of a pitting edema, if acupressure is performed, a surface imprint remains. Measuring the depth of the surface imprint is simple and, may be a valuable tool for use in the clinic. Thus, the purpose of this study was to develop and verify the reliability of a new practical evaluation method for pitting edema, which uses the depth of the surface imprint as an indicator.

\*Corresponding author. Haruki Kogo (E-mail: kogoha@nisikyuu-u.ac.jp)

**Table 1.** Subjects' characteristics (n = 26)

Age, years	85.0 ± 5.9
Gender, (male/female)	8/18
Height, cm	151.2 ± 7.6
Weight, kg	44.6 ± 9.2
BMI, kg/m <sup>2</sup>	19.4 ± 3.4
Heart disease, n	21
Central nerve disease, n	15
Pancreopathy, n	10
Orthopedic, n	8
Kidney disease, n	6
Pulmonary disease, n	5

BMI: body mass index

Data for age, height, weight, and BMI are presented as the mean ± SD.

## SUBJECTS AND METHODS

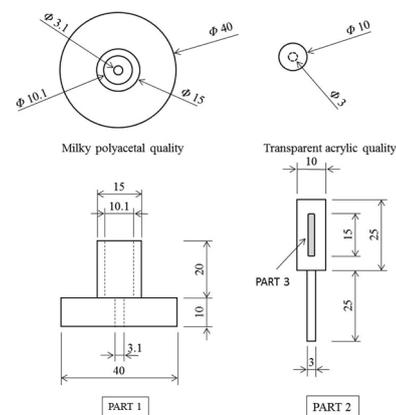
The subjects of this study were 26 inpatients (52 legs; 8 men, 18 women; average age, 85.0 ± 5.9 years) who were in a convalescent ward (Table 1). All subjects were diagnosed with edema by physical examination and palpation, and their general condition was comparatively stable. We excluded persons with dementia, etc., one leg, foot vulnerabilities, and those who were unavailable during the study period.

This study was performed in accordance with the Declaration of Helsinki. We sufficiently explained the details of the study to the subjects, and all participants signed informed consent. The study was approved by the Ethics Committee of the University of Nishikyushu (approval no.: H25-6).

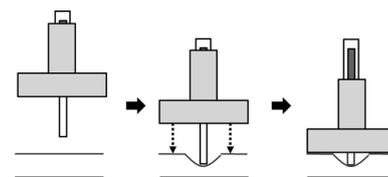
Before the study, we developed a measurement instrument (depth gauge for edema, KM-212-003; Unique Medical Company, Tokyo, Japan) to measure the depth of the surface imprint (Fig. 1). Figure 2 shows a working drawing of the depth gauge for edema, which has three parts. Part 1 is made of a milky polyacetal-quality material, and it makes contact with the region surrounding the surface imprint. The bottom portion is a wide rotund shape. Because the area for measuring a surface imprint is a narrow region on a peripheral extremity, the diameter of the surface imprint was postulated to be about 20 mm; thus, the diameter of the bottom of part 1 is 40 mm. Part 2 is made of an acrylic-like material that is transparent, and the tip of this part makes contact with the deepest portion of a surface imprint. Since it would not be able to make contact if it was too big and it would be painful to patients if it was too slim, we used a size of 3 mm, which was the optimal size after repeated test fabrications. Part 3 is the gauge itself, which is attached to part 2. In order to perform a visual measurement using the depth gauge for edema, we considered 0.5 mm as the measurement error. During the measurement procedure (Fig. 3), part 1 is held with the thumb, third finger, and fourth finger. Then, using a forefinger, part 2 is then pushed down a little more than the depth of the surface imprint. Next, after the tip of part 2 gently makes contact with the deepest region of the surface imprint, part 1 is pushed down until contact is made with the region of the surrounding surface imprint.



**Fig. 1.** Instrument to measure the depth of the surface imprint



**Fig. 2.** Construction drawing of the depth gauge for edema (left side, part 1; right side, parts 2, 3)



**Fig. 3.** Measurement procedure

When pushing down part 1, the depth gauge can be separated from the measurement part for visualization. One precaution during measuring is to perform the process gently so that the surface imprint portion is not pushed too much by the tip of part 2. The two parts were elaborately fabricated so that the device could slide smoothly while measuring and then rest at the time of the visual measurement—the pressing force becomes constant.

We instructed the subjects to sit on the edge of a chair and to lightly ground the soles of their feet into the floor. Then we measured the right and left sides during a relaxed condition so that muscular contraction was not initiated. We measured during the morning, which was considered the preinitiation of the examination or medical treatment. The measured region referred to in a previous study was the

**Table 2.** Intra-rater reliability of measurements

	Measurement	Depth of the surface imprint (mm)	ICC
Right foot dorsal	First time	3.01 ± 1.37	0.91**
	Second time	3.31 ± 1.44	
Left foot dorsal	First time	3.23 ± 1.29	0.97**
	Second time	3.39 ± 1.35	

Data are presented as mean ± SD. \*\*p < 0.01  
ICC: intraclass correlation coefficient

circumferential measuring method<sup>5</sup>). We pressed down for 10 sec on the back of the feet in the central region, on the line that connects the first os metatarsale caput of the bone and the fifth os metatarsale caput of the bone; approximately 2 kg of compressive force was used, as measured with a digital force gauge (FG-5005; Mother Tool Co., Ltd., Nagano, Japan), which was equipped with an attachment made of rubber. Thereafter, we measured the depth of the surface imprint for 10 sec. Each measurement was performed twice, and values were then averaged.

Two examiners at Maruyama Hospital performed the edema measurements on different dates, and we adopted a test-retest method to evaluate the degree of unanimity. To examine the intra-rater reliability, examiner A performed the measurement a second time on the next day after the patient had rested. To examine inter-rater reliability, examiner B measured the edema in the subjects after the surface imprint was restored. Examiner A had 10 years of clinical experience, while examiner B had 3 years of clinical experience.

We analyzed the inter- and intra-rater reliabilities of the measured values from the edema depth gauge using intraclass correlation coefficients (ICC). In the statistical analysis, we considered the level of significance at 5%, and SPSS version 21 for Windows (SPSS Inc., Tokyo, Japan) was used for all analyses.

## RESULTS

With regard to intra-rater reliability, the measured values of the depth of the surface imprint of the right dorsal foot using the edema gauge were 3.01 ± 1.37 for the first time and 3.31 ± 1.44 for the second time; the ICC was 0.91. The measured values of the depth of the surface imprint of the left dorsal foot were 3.23 ± 1.29 for the first time and 3.39 ± 1.35 for the second time; the ICC was 0.97 (Table 2).

With regard to inter-rater reliability, the measured value of the depth of the surface imprint of the right dorsal foot dorsal by examiner B was 3.06 ± 1.37; the ICC was 0.99. The measured value of the depth of the surface imprint of the left dorsal foot by examiner B was 3.21 ± 1.39, and the ICC was 0.97 (Table 3).

## DISCUSSION

We developed a practical evaluation method to easily measure the depth of the surface imprint of an edema. As a result of verifying the intra-rater reliability of this assessment technique, the ICC was 0.91 for the right dorsal foot and

**Table 3.** Inter-rater reliability of measurement

	Examiners	Depth of the surface imprint (mm)	ICC
Right foot dorsal	A	3.01 ± 1.37	0.99**
	B	3.06 ± 1.37	
Left foot dorsal	A	3.23 ± 1.29	0.97**
	B	3.21 ± 1.39	

The data are presented as mean ± SD. \*\*p < 0.01  
ICC: intraclass correlation coefficient

0.97 for the left dorsal foot, indicating a high consistency. Since examiner A performed the second measurement on the day following the first measurement, it was presumed that the measured value would change, but there was high consistency between measurements. This may be because the test subjects used in this study were in comparatively stable conditions. Therefore, that suggests measurements using the edema depth gauge are highly reproducible, even if we do not consider that the measurement was taken the next day.

Moreover, as a result of verifying the inter-rater reliability of the assessment technique, the ICC was 0.99 for the right foot dorsum and 0.97 for the left foot dorsum, showing a high consistency. Therefore, the inter-rater reliability of the measurements using the depth gauge for edema was also high. Thus, even if different examiners perform measurements, a practically identical result can be derived. This means that the assessment technique using the depth gauge for edema is highly reliable.

If an edema is defined as the superfluous stagnating condition of interstitial fluid, some questions arise about the quantifiable assessment technique of an edema. Interstitial fluid is not the same as intravital fluid. Additionally, it is 70% of the weight of soft tissue such as skin; alternatively, it is only about 10% of the weight of skeletal muscles<sup>13</sup>). Therefore, the validity of a quantitative evaluation of systemic interstitial fluid is unknown. However, measuring of the depth of the surface imprint is a vital and valid assessment of the peripheral region.

A circumferential measurement is an easy assessment technique to perform. According to a previous study on subjects with an edema, Brodovicz et al. measured ankle joint circumference<sup>7</sup>), an 8-character circumference using a tape measure, and lower leg volumetry using water displacement; they verified the inter-rater reliability of these three methods. However, these methods measured the entire body region, including all portio dura tissues (e.g., bone and soft tissues, including muscular and tallow). Therefore, there was no parameter that could evaluate an edema using only one measurement. In medical practice, a comparison of both sides using the measurements on different dates can be performed to determine the difference between sides, which can serve as an assessment of an edema. Conversely, it seems that the measured value using a depth gauge for edema may evaluate the condition of an edema using only one measurement.

We verified the reliability of this new assessment technique (the depth gauge for edema) that measured the depth of the surface imprint of pitting edema. We did not perform the measurement using existing assessment techniques.

There were certain limitations to this study. In particular, we did not verify the validity of the amount of changes in the circumference measurement or the measured depth of the surface imprint. Therefore, a future study should verify the relationship of the tela subcutanea thickness measured by an echo check, and the measured value of the depth of the surface imprint. In conclusion, the depth gauge we developed is a simple and reliable method for evaluating pitting edema.

#### ACKNOWLEDGEMENTS

The authors wish to thank the patients at Maruyama Hospital for their cooperation during this study. We would also like to thank all the staff, especially Mr. H. Toriyama from the hospital's rehabilitation department.

#### REFERENCES

- 1) Ohashi T: [Physiology of edema]. *Nippon Seirigaku Zasshi*, 2007, 69: 102–107 (in Japanese). [[Medline](#)]
- 2) Imanaka S, Yoshihara K, Koizumi S: [A case of polymyalgia rheumatica with swelling and pitting edema of the distal lower extremities]. *Nippon Ronen Igakkai Zasshi*, 1997, 34: 668–671 (in Japanese). [[Medline](#)] [[CrossRef](#)]
- 3) Tamaki K, Okuda S: Clinical approach to edema. *Sōgō rinshō Clinic all-round*, 2006, 55, 2594–2600. (in Japanese).
- 4) Taylor R, Jayasinghe UW, Koelmeyer L, et al.: Reliability and validity of arm volume measurements for assessment of lymphedema. *Phys Ther*, 2006, 86: 205–214. [[Medline](#)]
- 5) Mawdsley RH, Hoy DK, Erwin PM: Criterion-related validity of the figure-of-eight method of measuring ankle edema. *J Orthop Sports Phys Ther*, 2000, 30: 149–153. [[Medline](#)] [[CrossRef](#)]
- 6) Pellecchia GL: Figure-of-eight method of measuring hand size: reliability and concurrent validity. *J Hand Ther*, 2003, 16: 300–304. [[Medline](#)] [[CrossRef](#)]
- 7) Terada S, Gotou K: Investigation of a clinically useful technique for the evaluation of the foot shape—sensitivity of the FOE method and the validity of the screening tests—. *J Phys Ther Sci*, 2010, 22: 129–133. [[CrossRef](#)]
- 8) Brodovicz KG, McNaughton K, Uemura N, et al.: Reliability and feasibility of methods to quantitatively assess peripheral edema. *Clin Med Res*, 2009, 7: 21–31. [[Medline](#)] [[CrossRef](#)]
- 9) Maihafer GC, Llewellyn MA, Pillar WJ Jr, et al.: A comparison of the figure-of-eight method and water volumetry in measurement of hand and wrist size. *J Hand Ther*, 2003, 16: 305–310. [[Medline](#)] [[CrossRef](#)]
- 10) Hirota A: Treatment of lymphedema. Tokyo: Nagasaki Publication, 2011, pp 12–15. (in Japanese).
- 11) Arisawa M, Fukuba K, Seki T, et al.: [Assessment of degree of edema by means of bioelectrical impedance during pregnancy]. *Nippon Sanka Fujinka Gakkai Zasshi*, 1996, 48: 25–31 (in Japanese). [[Medline](#)]
- 12) Rutkove SB: Electrical impedance myography: background, current state, and future directions. *Muscle Nerve*, 2009, 40: 936–946. [[Medline](#)] [[CrossRef](#)]
- 13) Yoshitoshi Y: The task of an edema doctrine. *Nippon Rinsho*, 1982, 40: 7–9 (Article in Japanese).