

Novel Assessment Technique: Ring Gauge Measurement of Finger Joint Circumference Changes in Patients with Rheumatoid Arthritis

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Abstract

Objectives: As therapeutic modalities for rheumatoid arthritis (RA) advance, immediate and quantitative determination of RA disease status is becoming increasingly important. The purpose of this study was to validate the usefulness of a ring gauge as a simple semiquantitative method for assessing hand swelling in patients with RA. **Methods:** We enrolled patients diagnosed with RA either initiated or switched to a biological therapeutic agent. The circumference of the interphalangeal (IP) joint and the proximal interphalangeal (PIP) joint was measured using a ring gauge. Assessments of the joint echocardiography, incorporating both Gray Scale (GS) and Power Doppler (PD) imaging, were conducted. These evaluations were performed both before the initiation of biological agent treatment and 28 days after the initial dose. **Results:** Following the treatment intervention, a significant reduction was observed in the circumference of the joint from the thumb to the little finger ($p < 0.01$). The relationship between changes in the ring gauge and joint ultrasound changes was examined, revealing a ring gauge cutoff value of 2 in the receiver operating characteristic curve analysis of GS change. **Conclusions:** Our study demonstrated the effectiveness of using a ring gauge as a simple assessment tool for RA, revealing that a change in the ring gauge number by 2 or more corresponded to either improvement or deterioration in synovial thickening detected via joint echocardiography.

Keywords

Disease Activity, Interphalangeal Joint, Rheumatoid Arthritis, Ring Gauge, Semi-Quantitative Evaluation

1. Introduction

According to recommendations from the American College of Rheumatology (ACR) and the European League Against Rheumatism (EULAR), managing rheumatoid arthritis (RA) often involves a combination therapy comprising non-biologic disease-modifying antirheumatic drugs (DMARDs) alongside biologic DMARDs when methotrexate (MTX) treatment alone proves inadequate [1] [2]. While therapeutic interventions frequently reduce disease activity and improve serological inflammatory responses, such as C-reactive protein (CRP) levels, persistent multiple swollen and tender joints can occur, posing challenges in assessing swelling in finger joints. The Clinical Disease Activity Index (CDAI), introduced in 2014, is valuable for its exclusion of inflammatory biomarkers [1]. However, its boolean calculation method makes assessing the extent of local inflammatory manifestations challenging.

Similarly, joint ultrasonography has also been employed to evaluate the degree of local inflammatory manifestations, allowing quantitative assessment of both synovial thickening and blood flow signals. However, evaluating multiple joints simultaneously can be time-consuming. To overcome these constraints, Nakamura *et al.* conducted a study on 300 healthy individuals and found that the circumferential diameter of the thumb interphalangeal (IP) joint and the proximal interphalangeal (PIP) joints from the index to the little finger could be estimated using a ring gauge number based on age, gender, height, weight, and dominant hand [3]. We hypothesised that using a ring gauge to assess the efficacy of biological drugs in RA treatment could facilitate simplified semi-quantitative evaluations.

Therefore, this study aimed to evaluate the effectiveness of using a ring gauge as a semi-quantitative measure in assessing the efficacy of biologics among patients with RA whose condition is inadequately controlled.

2. Materials and Methods

2.1. Participants

We recruited patients with RA who either newly started a biological drug or switched to one. These individuals were outpatient attendees at the Department of Orthopaedics, Kyoto Prefectural University of Medicine Hospital, and Orthopaedic departments at affiliated hospitals, meeting the criteria set by the American College of Rheumatology (ACR) established in 1987.

This study was conducted with approval (RBMR-C-1291-1) from the Ethics Committee of the Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kyoto, Japan. All people gave their informed consent prior to their inclusion in the study.

2.2. Evaluations

At the start, the estimated circumferential diameters of the thumb IP joint and the PIP joints from the index to the little finger in healthy participants were computed

using the formula previously established by Nakamura *et al.* This formula takes into account parameters such as age, gender, height, weight, and handedness.

Subsequently, we employed a ring gauge (Japan Custom Size, ART No. 40610, size #1 - #30) manufactured by Meikosha Seisakusho Co., Ltd. (Nagoya City) to measure the circumference of both the thumb IP joint and the PIP joint spanning from the index to the little finger. Additionally, we conducted assessments of Disease Activity Score 28 with C-Reactive Protein (DAS28-CRP) and joint echocardiography, encompassing both Gray Scale (GS) and Power Doppler (PD) imaging. These evaluations were performed both before the initiation of biological agent administration and 28 days following the initial dose.

Briefly, the Japan Custom Size ring gauge, depicted in **Figure 1**, was employed to measure the circumference. This ring gauge is widely used in Japan. It is designed such that with each increment of 1, the diameter increases by approximately 1/3 mm, and the inner circumference expands by approximately 1 mm. To mitigate examiner bias, different physicians performed both the ring gauge measurements and DAS28-CRP evaluations. To ensure circumference measurement reproducibility using the ring gauge, we employed a method where gauges with larger numbers were initially used, followed by those with smaller numbers. The smallest diameter ring gauge numbers capable of passing through the thumb IP joint and each of the PIP joints, from the index finger to the little finger, were recorded.

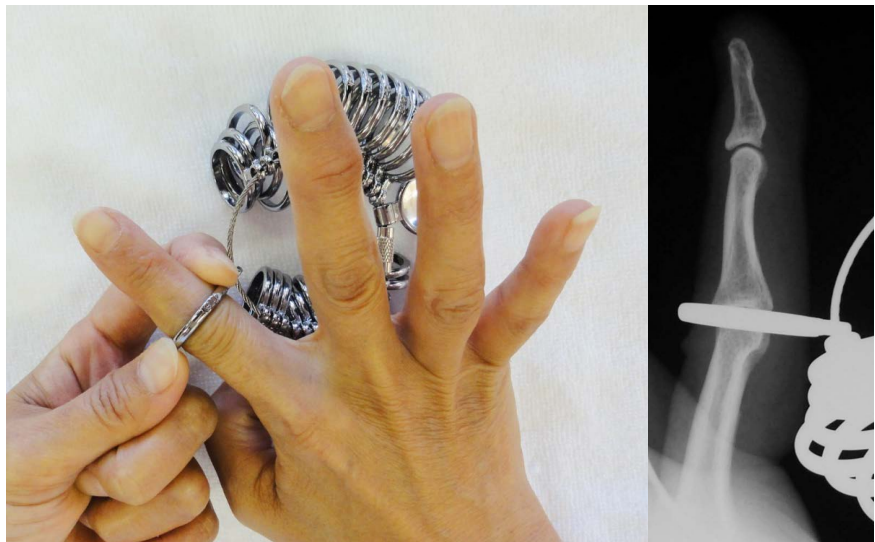


Figure 1. An illustration depicting a Japan Custom Size standard ring gauge (Meikosha Mfg. Co., Ltd., Nagoya, Japan). X-ray demonstrates the widest position in diameter of the PIPJ.

The digital ultrasound diagnostic device used for joint echocardiography was the HI VISION Avius, manufactured by Hitachi Aloka Medical Co., Ltd. A specialist from the Japan Rheumatology Society captured images of the dorsal sides of the (P) IP joints of all fingers, following the imaging protocol established by the Rheumatoid Arthritis Ultrasound Standardisation Committee of the Japan Rheumatology Society. Evaluation using the Power Doppler Ultrasound (PDUS) scoring

system was conducted independently by three physicians who were blinded to the results obtained from other assessments. Data obtained in GS mode were used to assess synovial thickening, while data acquired in PD mode were employed to evaluate synovial blood flow signals.

Receiver Operating Characteristic (ROC) curves were employed to explore the relationship between changes observed in joint ultrasound findings and alterations in ring size. Ring gauge changes served as the explanatory variable, while changes in dorsal GS and dorsal PD represent the outcome variables.

2.3. Statistical Analysis

All analyses were performed using right-hand data. To assess the change in ring gauge over time, a paired t-test was conducted by subtracting the actual measured value from the predicted value derived from healthy participants. The effectiveness of joint ultrasound was assessed using the Wilcoxon rank sum test. Additionally, the area under the curve (AUC) was computed to determine the degree of association between the ring gauge number and ultrasound readings. An AUC of 0.9 - 1.0 was considered indicative of high accuracy, 0.7 - 0.9 of moderate accuracy, and 0.5 - 0.7 of low accuracy. Data were presented as mean \pm standard deviation (SD), and statistical significance was set at $p > 0.05$.

3. Results

3.1. Participants' Characteristics

A total of 20 patients were included in this study, with no withdrawals or dropouts occurring during the study. The participants comprised 18 females and 2 males, aged 33 to 78 years (average age: 60.5 years), and disease durations ranging from 8 months to 30 years (average duration: 11.3 years). The biological agents administered included infliximab in one case, etanercept in three, adalimumab in four, certolizumab pegol in three, tocilizumab in two, golimumab in one, and abatacept in five. The DAS28-CRP decreased significantly from 4.28 ± 1.05 before the administration of the biological agent to 2.72 ± 0.95 28 days after administration ($p < 0.01$).

3.2. Evaluation

3.2.1. Changes in Ring Gauge

Table 1 presents the estimated circumferential diameters of the thumb IP joint and the index to little finger PIP joint circumferences for 20 patients with RA, calculated using the previously established formula. Additionally, it includes the actual measured values before and after 28 days of intervention. Remarkably, the actual measured values in patients with RA were found to be significantly larger than the predicted values in healthy participants ($p < 0.01$). Following therapeutic intervention, significant reductions were observed in both the circumference of the thumb IP joint and the diameter of the PIP joint from the index to the little finger among patients with RA ($p < 0.01$).

Table 1. Changes in ring size before and after administration of biologics (mm).

	Healthy predicted value	Pre-administration	28 days after administration	Change pre-administration	Change post-administration	p-value
Thumb	16.6 ± 3.7	20.1 ± 5.0	18.7 ± 5.1	3.5 ± 2.6	2.1 ± 2.6	0.0002
Index	11.9 ± 3.1	15.0 ± 3.8	16.8 ± 3.8	3.1 ± 3.1	1.9 ± 2.9	<0.0001
Middle	12.6 ± 3.4	17.4 ± 4.5	15.6 ± 4.4	4.8 ± 3.6	3.0 ± 3.3	<0.0001
Ring	9.6 ± 3.1	13.2 ± 4.7	11.5 ± 4.2	3.6 ± 3.6	1.9 ± 3.2	<0.0001
Little	4.0 ± 2.7	7.0 ± 4.0	5.7 ± 3.4	2.9 ± 2.6	1.7 ± 2.0	<0.0001

Change pre-administration: Ring size before administration – healthy predicted value. Change post-administration: Ring size 28 days after administration – healthy predicted value.

3.2.2. Joint Ultrasound Tests

Substantial improvements were observed in both synovial thickening and synovial blood flow signals across nearly all joints (**Table 2** and **Table 3**).

Table 2. Changes in joint ultrasound and Gray Scale mode, before and after administration of biologics (n = 20).

Thumb	Pre	28 days		Ring	Pre	28 days	
Stage 0	0	6		Stage 0	7	11	
1	9	10		1	6	7	
2	11	4	p-value	2	6	2	p-value
3	0	0	0.022	3	1	0	0.0077
Index	Pre	28 days		Little	Pre	28 days	
Stage 0	7	13		Stage 0	4	8	
1	6	6		1	7	6	
2	6	1	p-value	2	7	4	p-value
3	1	0	0.0033	3	2	2	0.0051
Middle	Pre	28 days					
Stage 0	5	11					
1	7	7					
2	4	1	p-value				
3	4	1	0.0033				

Pre: Before administration of the biological agent. 28 days: 28 days after administration of the biological agent.

Table 3. Changes in joint ultrasound and Power Doppler mode, before and after administration of biologics (n = 20).

Thumb	Pre	28 days		Ring	Pre	28 days
Stage 0	17	19		Stage 0	14	19
1	1	0		1	5	1

Continued

2	2	1	p-value	2	1	0	p-value
3	0	0	0.0178	3	0	0	0.0277
Index	Pre	28 days		Little	Pre	28 days	
Stage 0	16	20		Stage 0	16	20	
1	2	0		1	4	0	
2	2	0	p-value	2	0	0	p-value
3	0	0	0.0679	3	0	0	0.0431
Middle	Pre	28 days					
stage 0	14	18					
1	2	2					
2	4	0	p-value				
3	0	0	0.0277				

Pre: Before administration of the biological agent. 28 days: 28 days after administration of the biological agent.

3.2.3. Relationship between Ring Gauge Changes and Joint Ultrasound Changes

In the ROC curve analysis of GS change, the cutoff value of the ring gauge was established as 2. At this cutoff, the sensitivity was found to be 0.545, with a specificity of 0.717, and the AUC was calculated as 0.70, indicating a moderate level of accuracy (**Figure 2**). Similarly, in the ROC curve analysis of PD change, the cutoff

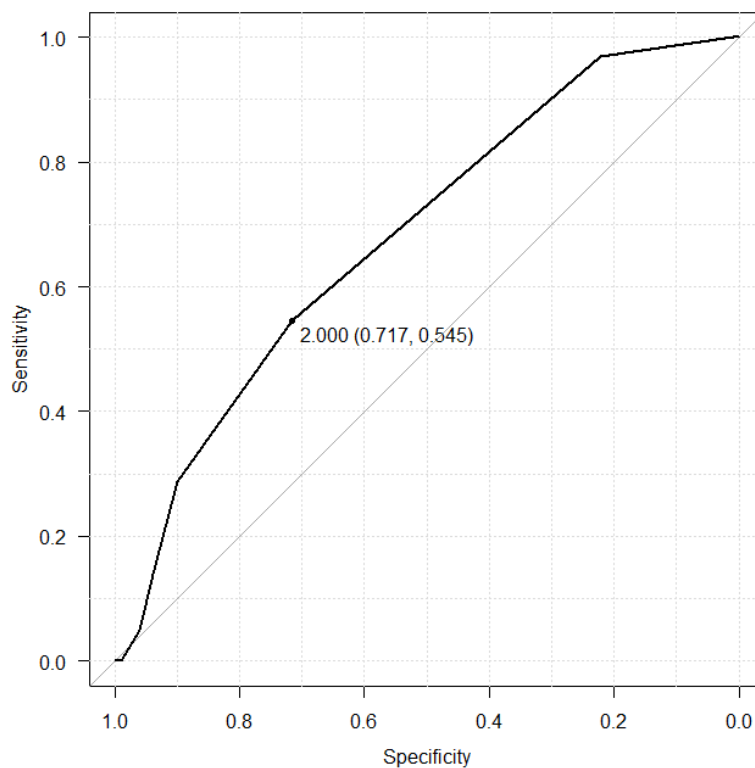


Figure 2. Relationship between ring size and joint ultrasound, GS mode.

value of the ring gauge was determined to be 1. At this cutoff, the sensitivity was 0.155, with a specificity of 1.000, and the AUC was calculated as 0.58, indicating a low level of accuracy (**Figure 3**).

The cutoff value was 2, sensitivity was 0.545, specificity was 0.717, and area under the curve (AUC) was 0.70, indicating moderate accuracy.

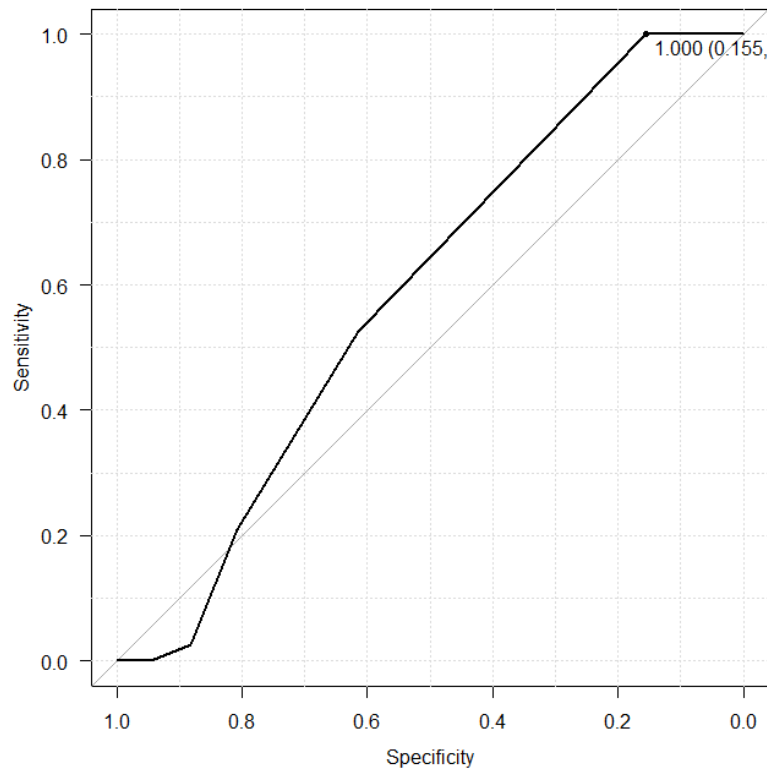


Figure 3. Relationship between ring size and joint ultrasound, PD mode.

The cutoff value of the ring gauge was 1, sensitivity was 0.155, specificity was 1.000, and area under the curve (AUC) was 0.58, indicating low accuracy.

4. Discussion

Since the introduction of tumor necrosis factor-alpha inhibitors into the treatment of RA, therapeutic strategies for RA have changed dramatically. Especially in cohort studies with large numbers of patients, all-or-nothing Boolean assessments were introduced to determine RA disease status for the purpose of determining drug efficacy. However, the Boolean evaluation alone is not sufficient for the evaluation of individual patients, and ultrasonography has attracted attention as a more accurate method of evaluation and is now widely used.

In clinical practice, ultrasonography and magnetic resonance imaging (MRI) are used for imaging evaluation of finger PIP joint swelling [4]-[9]. Recently, ultrasound testing is gaining popularity due to advancements in hardware, and its main advantage lies in its non-invasive nature. The synovial membrane within the joint is not planar, particularly in the finger PIP joint, where it extends from the

joint space towards the proximal dorsal side, allowing for precise observation via ultrasonography [8] [9]. Studies comparing PD scores between DAS28 and ultrasound findings have shown a stronger correlation between ultrasound and the progression of joint destruction over time [10]. For instance, a comparison of joint destruction progression over a one-year period was made using baseline examination findings, MRI findings, and ultrasound findings in patients with RA in clinical remission. While clinical examination findings were found to be unable to predict the progression of joint destruction, it was reported that ultrasonographic PD findings could predict such progression with an odds ratio of 12.21 times [11]. Additionally, Fukae *et al.* have reported that bone destruction advances in joints where PD does not show improvement on finger joint ultrasonography, even after the administration of biologics. Furthermore, they highlighted that persistent PD signals contribute to the formation of bone erosions [12] [13]. However, ultrasound examinations have limitations, including lengthy examination times, high inter-examiner and intra-examiner errors [14], and PD sensitivity that varies depending on the ultrasound examination equipment [15]. Thus, ultrasound examinations are not necessarily simple examinations.

Helliwell *et al.* employed a specialized device called the “Leeds Dactylometer” to measure finger circumference for diagnosing dactylitis, a common complication of axial spondylitis, including conditions like ankylosing spondylitis and psoriatic arthritis [16]. Afterward, the accuracy of finger circumference measurement using the device was assessed. However, the widespread use of the Dactylitis Score [17], which involves comparing the circumferential diameter of the affected finger with that of the contralateral side and assessing the presence or absence of tenderness, is limited due to challenges in evaluating cases with bilateral disease and variability in tenderness assessment. Consequently, in this study, we employed a ring gauge, which is more readily accessible compared to the Leeds Dactylometer.

To tackle these issues, we employed a ring gauge in this study to evaluate joint swelling. Our results showed that a reduction in ring gauge numbers correlated with improvements in synovial thickening on joint echocardiograms. Thus, in conditions such as RA, where there are rapid changes in the circumferential diameter of the finger PIP joint due to fluctuations in disease status or therapeutic approaches, changes over time can be readily monitored using a ring gauge. Moreover, our findings revealed that altering the ring gauge number by 2 or more influenced the GS results. Particularly, if the ring gauge number changes by 2 or more from the initial value, it suggests an improvement or deterioration in synovial thickening, potentially guiding therapeutic interventions.

A limitation of this study is the relatively small sample size. Despite observing a significant difference even in the limited sample of 20 cases, it is reasonable to anticipate that this difference would become more pronounced with an increase in the number of cases. However, we contend that expanding the sample size is crucial for conducting a more comprehensive evaluation, particularly concerning the various types of biologics and their interactions with other DMARDs.

Additionally, there are multiple standards for ring gauges, and they are not universal (**Table 4**). The International Organisation for Standardisation (ISO) advocates for the standardisation of ring gauges with inner diameters in 1 mm intervals, ranging from 41 mm to 76 mm. However, such standardisation is currently uncommon. Nevertheless, in this study, we employed a Japanese standard ring gauge and demonstrated its effectiveness in evaluating disease activity among patients with RA. To promote the widespread adoption of measurement methods using ring gauges in the future, we propose that the development of a globally standardised ring gauge would be crucial.

Table 4. Comparison of ring sizes in each country.

Inside diameter (mm)	JPN	USA	UK	CHN
12.85	1	1.5	C	
13.26	2	2	D	
13.67	3	2.5	E	
14.07	4	3	F	6
14.48	5	3.5	G	7
14.68	6	4	G1/2	
14.97	7	4.5	H1/2	8
15.29	8	5	I1/2	9
15.61	9	5.5	J1/2	
16.1	10	6	K1/2	

CHN: China; JPN: Japan; UK: United Kingdom; USA: United States of America.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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