



Understanding the use of thermography and its ability to predict ultrasound-detected joint inflammation at the metacarpophalangeal joint in patients with rheumatoid arthritis

YK Tan & PG Conaghan

To cite this article: YK Tan & PG Conaghan (29 Aug 2025): Understanding the use of thermography and its ability to predict ultrasound-detected joint inflammation at the metacarpophalangeal joint in patients with rheumatoid arthritis, Scandinavian Journal of Rheumatology, DOI: [10.1080/03009742.2025.2548061](https://doi.org/10.1080/03009742.2025.2548061)

To link to this article: <https://doi.org/10.1080/03009742.2025.2548061>



© 2025 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



[View supplementary material](#)



Published online: 29 Aug 2025.



[Submit your article to this journal](#)



Article views: 199



[View related articles](#)



[View Crossmark data](#)

Understanding the use of thermography and its ability to predict ultrasound-detected joint inflammation at the metacarpophalangeal joint in patients with rheumatoid arthritis

YK Tan^{1,2,3}, PG Conaghan⁴

¹Department of Rheumatology and Immunology, Singapore General Hospital, Singapore

²Duke-NUS Medical School, Singapore

³Yong Loo Lin School of Medicine, National University of Singapore, Singapore

⁴Leeds Institute of Rheumatic and Musculoskeletal Medicine, University of Leeds and NIHR Leeds Biomedical Research Centre, Leeds, UK

Objectives: To study the correlation of thermography with ultrasonography, and whether thermography can help to predict ultrasound-detected joint inflammation at the metacarpophalangeal joints (MCPJs) in patients with rheumatoid arthritis (RA).

Method: Maximum, average, and minimum temperatures were recorded by thermography and summed for the MCPJs of each hand. Their relationship with the summed power Doppler (PD) and grey-scale (GS) scores was explored using correlation analysis and simple linear regression. The ability of summed thermographic temperatures to predict summed PD score ≥ 1 and summed GS score ≥ 18 (median score) was studied using receiver operating characteristics (ROC) curve analysis. Intraobserver reliability (single observer) was analysed using intraclass correlation coefficients (ICCs).

Results: This cross-sectional study examined 810 joints from 81 RA patients. At both right and left MCPJs, all summed thermographic temperatures correlated significantly ($p < 0.05$) and had significant relationships ($p < 0.05$) with summed ultrasound scores (for PD and GS, respectively, correlation coefficients ranged from 0.45 to 0.52 and 0.26 to 0.29, and regression coefficients from 0.094 to 0.137 and 0.058 to 0.086). At the bilateral MCPJs, the area under the ROC curves for summed thermographic temperatures in predicting summed PD score ≥ 1 and summed GS score ≥ 18 ranged from 0.80 to 0.82 and 0.65 to 0.66, respectively. ICC values (for 45 baseline MCPJs for which thermographic temperatures were resegmented > 2 weeks apart) were excellent (all > 0.90).

Conclusion: Thermographic temperatures reflect ultrasound-detected joint inflammation, and appear useful in predicting PD vascularity at the MCPJs of patients with RA.

Infrared thermography can be used to objectively quantify joint inflammation by detecting joint surface temperatures in patients with rheumatoid arthritis (RA) (1). Thermography detects heat signatures overlying inflamed joints, although, unlike ultrasound, it does not directly visualize the inflamed synovium (1, 2) and bone erosions, nor does it differentiate the morphological substrate of the inflammatory process (synovitis, tenosynovitis, enthesitis, etc.). Nonetheless, thermography has its own strengths and attributes, making it

a promising imaging modality for the assessment of joint inflammation in RA. First, thermography is non-invasive, requiring less training than ultrasonography for its operators (1, 3). Image acquisition, although simple, requires standardization (e.g. ambient conditions) and subsequent timely image processing for consistent results. Moreover, there is a need to establish validated cut-off values for data interpretation. Secondly, modern handheld thermal cameras are compact and highly portable, with quick image acquisition and digital readouts that are easy and convenient to use in the rheumatologist's office, and cost less than magnetic resonance imaging and ultrasound machines (1, 3–5). Finally, being contactless, thermography can potentially be used in remote telemedicine consultations, in which physical examination of patients is not possible (6).

York Kiat Tan, Department of Rheumatology and Immunology, Singapore General Hospital, Outram Road, 169608, Singapore.
E-mail: tan.york.kiat@singhealth.com.sg

Received 16 June 2025; Accepted 12 August 2025

© 2025 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

DOI: <https://doi.org/10.1080/03009742.2025.2548061>

www.scandjrheumatol.se

These reasons provide a good rationale to explore thermography in assessing RA joint inflammation. In this study, the metacarpophalangeal joints (MCPJs) were chosen as these are commonly affected in patients with RA and hence provide a good model for studying synovial inflammation. We aimed (i) to study the correlation of thermography with ultrasonography, and (ii) to assess whether thermography can help to predict ultrasound-detected joint inflammation at the MCPJs of patients with RA.

Method

This cross-sectional study, conducted at the Singapore General Hospital, was approved by the local institutional review board and conforms to the relevant research ethical guidelines. Patients fulfilling the 2010 RA classification criteria (7) and other recruitment criteria (Supplementary Table S1) were consecutively recruited from the hospital's rheumatology outpatient clinic. All patients provided written informed consent before enrolment.

Baseline patient characteristics

Patient characteristics, obtained from their medical records, were: 28-joint Disease Activity Score (DAS28), age, ethnicity, sex, disease duration, and medication use.

Imaging assessment

Ultrasonography and thermography were performed independently during the same patient study visit. Dorsal recesses of bilateral MCPJs 1–5 were scanned by a rheumatologist with > 10 years of experience in musculoskeletal ultrasound, blinded to the findings from thermography. A Mindray M9 (Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China) ultrasound machine (with settings at Doppler frequency 5.7 MHz and pulse repetition frequency 700 Hz) with an L14-6Ns linear probe (frequency range 6–14 MHz) set at 12 MHz were used for scanning. Ultrasonography followed the European Alliance of Associations for Rheumatology (EULAR) guidelines (8), while power Doppler (PD) vascularity and grey-scale (GS) synovial hypertrophy were scored separately and each graded semi-quantitatively (0–3) using validated scoring methods (9). In our study, which focuses on synovitis assessment, other structures (e.g. tendons, erosions, or features of osteoarthritis such as osteophytosis) were not evaluated.

Thermography was performed by a trained study team member (blinded to the findings of the ultrasonography) in a standardized manner following established methods (1, 10, 11), using a high-performance thermal

camera FLIR T865 (Teledyne FLIR, OR, USA) with pixel resolution of 640 × 480, thermal sensitivity of < 30 mK at 30°C and predefined emissivity value of 0.98 for skin (1). Thermography was performed in a windowless, draught-free room in a facility with a central cooling system, with a measured ambient temperature of around 23°C (10). Patients were acclimatized by being rested for 15 min before starting thermography (1, 10). Physical objects blocking the thermal camera's view were removed. The dorsal aspect of each hand was imaged by placing the thermal camera 50 cm directly above the hand, which was placed on a flat tabletop. Following the commonly used region of interest (ROI) manual segmentation approach (1, 11) (Supplementary Figure S1), the maximum ($T_{\max}$), average (T_{avg}), and minimum ($T_{\min}$) temperatures were obtained from the ROIs of the MCPJs for each hand thermogram.

Statistical analysis

The $T_{\max}$, T_{avg} , and $T_{\min}$ were summed at the MCPJs for each hand and compared with the summed PD and GS scores. Correlation analysis was performed using the Spearman's correlation coefficient, while relationship between variables were analysed using simple linear regression. At the bilateral MCPJs 1–5, the ability of the summed thermographic temperatures to predict summed PD score ≥ 1 and summed GS score ≥ 18 (median score) was studied using receiver operating characteristics (ROC) analysis. Without general consensus on what constitutes a higher or lower GS inflammatory burden at bilateral MCPJs 1–5, the median (50th percentile) summed GS score was arbitrarily used as a cut-off to categorize them into two groups: those with a higher summed GS score versus those with a lower summed GS score. For the ROC analysis, the 'closest to top left' method was applied to determine the optimal cut-off, which was used to obtain the corresponding sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Forty-five MCPJ ROIs were manually resegmented (> 2 weeks apart) from a subset of baseline thermograms, and the intraobserver reliability (single observer) was tested using the intraclass correlation coefficient (ICC). The ICC results were interpreted as follows (12): low (< 0.40), moderate (0.40–0.74), substantial (0.75–0.90), and excellent (> 0.90). Statistical analyses were performed using SPSS version 26 statistical software (IBM Corp, Armonk, NY, USA).

Results

Baseline patient characteristics

Eighty-one patients had 810 joints examined. Of these, 53 patients were Chinese (65.4%) and 59 patients were

female (72.8%). The mean $\pm$ sd age was 54.9 ± 14.4 years, disease duration was 7.3 ± 6.3 months, and DAS28 was 3.7 ± 1.3 . (See Supplementary Table S2 for baseline DAS28 subcomponents and medication use).

Correlation analysis

At the right and left MCPJs, all summed thermographic temperatures correlated significantly ($p < 0.05$) with the summed ultrasound scores (Table 1), although the correlation appeared stronger for the summed PD score (correlation coefficients ranged from 0.45 to 0.52) than for the summed GS score (correlation coefficients ranged from 0.24 to 0.29).

Regression analysis

At the right and left MCPJs, a significant relationship ($p < 0.05$) was demonstrated between all summed thermographic temperatures (Table 2) and the summed ultrasound scores. For the summed PD score, the regression coefficients ranged from 0.094 to 0.137. For the

summed GS score, the regression coefficients ranged from 0.058 to 0.086.

ROC analysis

For the bilateral MCPJs, the area under the ROC curve (AUC) values were higher for the summed thermographic temperatures when used in predicting the summed PD score ≥ 1 (AUC 0.80–0.82) than when used in predicting the summed GS score ≥ 18 (AUC 0.65–0.66). The cut-off values, sensitivity, specificity, PPV, and NPV results are summarized in Table 3.

Intraobserver reliability

The ICC values (single observer) for 45 manually resegmented MCPJ ROIs were high: the ICCs (95% confidence interval) of $T_{\max}$, T_{avg} , and $T_{\min}$ were 0.9994 (0.9990–0.9997), 0.9996 (0.9993–0.9998), and 0.9990 (0.9980–0.9993), respectively.

Discussion

In this study, we have shown that thermographic temperatures were reflective of ultrasound-detected joint

Table 1. Correlation analysis of thermography versus ultrasound variables.

Thermographic parameter	Summed PD score		Summed GS score	
	Correlation coefficient	p	Correlation coefficient	p
Right first to fifth MCPJs				
Summed $T_{\max}$	0.52	< 0.001	0.26	0.020
Summed T_{avg}	0.52	< 0.001	0.26	0.019
Summed $T_{\min}$	0.50	< 0.001	0.24	0.031
Left first to fifth MCPJs				
Summed $T_{\max}$	0.51	< 0.001	0.29	0.008
Summed T_{avg}	0.50	< 0.001	0.27	0.015
Summed $T_{\min}$	0.45	< 0.001	0.24	0.032

PD, power Doppler; GS, grey-scale; MCPJ, metacarpophalangeal joint; $T_{\max}$, maximum temperature; T_{avg} , average temperature; $T_{\min}$, minimum temperature.

Table 2. Comparison of the relationship between thermography and ultrasound variables.

Thermographic parameter	Summed PD score		Summed GS score	
	β Coefficient (95% CI)	p	β Coefficient (95% CI)	p
Right first to fifth MCPJs				
Summed $T_{\max}$	0.100 (0.050–0.150)	< 0.001	0.062 (0.010–0.114)	0.021
Summed T_{avg}	0.103 (0.053–0.153)	< 0.001	0.063 (0.011–0.115)	0.019
Summed $T_{\min}$	0.094 (0.044–0.143)	< 0.001	0.058 (0.006–0.109)	0.029
Left first to fifth MCPJs				
Summed $T_{\max}$	0.135 (0.080–0.190)	< 0.001	0.086 (0.032–0.139)	0.002
Summed T_{avg}	0.137 (0.083–0.192)	< 0.001	0.081 (0.027–0.134)	0.004
Summed $T_{\min}$	0.120 (0.067–0.173)	< 0.001	0.072 (0.021–0.123)	0.007

PD, power Doppler; GS, grey-scale; MCPJ, metacarpophalangeal joint; CI, confidence interval; $T_{\max}$, maximum temperature; T_{avg} , average temperature; $T_{\min}$, minimum temperature.

Table 3. Use of thermographic parameters in identifying ultrasound joint inflammation severity/activity.

Thermographic parameter	AUC (95% CI)	Cut-off*	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Bilateral first to fifth MCPJs (in identifying summed PD score ≥ 1)						
Summed $T_{\max}$	0.82 (0.72–0.92)	316.8	84.7	68.2	87.7	62.5
Summed T_{avg}	0.81 (0.70–0.92)	306.7	79.7	68.2	87.0	55.6
Summed $T_{\min}$	0.80 (0.69–0.92)	299.5	78.0	72.7	88.5	55.2
Bilateral first to fifth MCPJs (in identifying summed GS score ≥ 18)						
Summed $T_{\max}$	0.65 (0.53–0.77)	318.7	76.7	44.7	61.1	63.0
Summed T_{avg}	0.66 (0.54–0.78)	310.5	69.8	52.6	62.5	60.6
Summed $T_{\min}$	0.66 (0.54–0.78)	302.2	69.8	52.6	62.5	60.6

*Cut-off determined using the 'closest to top left' method.

AUC, area under the receiver operating characteristics curve; CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value; MCPJ, metacarpophalangeal joint, PD, power Doppler; GS, grey-scale; $T_{\max}$, maximum temperature; T_{avg} , average temperature; $T_{\min}$, minimum temperature.

inflammation, demonstrating a stronger association with PD than with GS joint inflammation. The summed thermographic temperatures at the MCPJs performed well (with AUC ≥ 0.8) in identifying PD vascularity, a key component of ultrasound-detected joint inflammation (4, 13).

There have been limited studies evaluating the performance of thermography in discriminating RA joint inflammation severity and disease activity (1). A small-scale study on the hands and wrists in RA demonstrated higher thermographic temperatures in PD-positive joints and GS-positive joints, although discriminating ultrasound-detected joint inflammation severity using thermography was not assessed (11). Morales-Ivorra et al (14) demonstrated that a joint inflammation score based on computational analysis of hand thermal images can help to identify patients (31 RA patients at baseline) who transited over 3 months from 28-swollen joint count (SJC28) > 1 to SJC28 ≤ 1 (with AUC result of 0.71). Triantafyllis et al (15) evaluated a high-resolution thermography marker, using hotspot/ROI ratio values, and demonstrated an AUC of 0.72 in discriminating between 267 finger joints (from 30 patients with mixed inflammatory arthritis) with and without PD score ≥ 1 and GS score > 0 . The above three studies (11, 14, 15) and our study suggest that thermography is promising in assessing hand joint inflammation in RA.

Our study has several limitations. It has a cross-sectional design; hence, a future longitudinal study with thermography performed at multiple time-points will be necessary to explore its responsiveness. The focus on MCPJs in our study limits the generalizability of the findings (e.g. to other joint types). Future studies will be needed to explore the use of thermography at various other joint sites, especially given thermography's ability to assess multiple joints simultaneously. We analysed the intraobserver reliability of thermography for a single observer. Subsequent RA studies with more than one observer will be necessary to assess interobserver reliability. We used an ROI manual segmentation approach for thermography. We envisage research innovation enabling computer-assisted

automated detection to help to advance this technology for remote RA telemedicine consultations. We did not split our data into smaller subgroups to compare thermography with ultrasonography based on clinical joint status (e.g. in patients with at least one swollen joint). This is an important topic for future research, and larger scale RA studies will be required to evaluate this aspect. In our study, we did not include a control group. Future studies should ideally incorporate a control group (e.g. healthy subjects) for comparative analysis.

Conclusion

We have demonstrated that thermographic temperatures at the MCPJs were reflective of ultrasound-detected joint inflammation, with stronger association with PD than with GS joint inflammation, and appear useful in predicting PD vascularity in RA patients.

Acknowledgements

We thank staff and colleagues from the study site for the help and support provided in this study. PGC is supported, in part, by the National Institute for Health Research (NIHR) Leeds Biomedical Research Centre (NIHR203331). The views expressed are those of the authors and not necessarily those of the National Health Service, the NIHR, or the Department of Health.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research is supported by the Singapore Ministry of Health's National Medical Research Council under its Clinician Scientist Award Investigator (INV) Category [CSAINV20nov-0004].

Data availability statement

Data are available from the corresponding author upon reasonable request.

Supplementary material

Supplemental data for this article can be accessed online at <https://doi.org/10.1080/03009742.2025.2548061>

ORCID

YK Tan  <http://orcid.org/0000-0002-6944-8220>

PG Conaghan  <http://orcid.org/0000-0002-3478-5665>

References

1. Kow J, Tan YK. An update on thermal imaging in rheumatoid arthritis. *Joint Bone Spine* 2023;90:105496.
2. Colebatch AN, Edwards CJ, Østergaard M, van der Heijde D, Balint PV, D'Agostino MA, et al. EULAR recommendations for the use of imaging of the joints in the clinical management of rheumatoid arthritis. *Ann Rheum Dis* 2013;72:804–14.
3. Tan YK, Chew LC, Allen JC Jr, Lye WK, Htay LL, Hassan A, et al. Utility of ultrasonography in guiding modification of disease modifying anti-rheumatic drugs and steroid therapy for inflammatory arthritis in routine clinical practice. *Int J Rheum Dis* 2018;21:155–60.
4. Elangovan S, Tan YK. The role of musculoskeletal ultrasound imaging in rheumatoid arthritis. *Ultrasound Med Biol* 2020;46:1841–53.
5. Tan YK, Conaghan PG. Insights into osteoarthritis from MRI. *Int J Rheum Dis* 2012;15:1–7.
6. Morales-Ivorra I, Narváez J, Gómez-Vaquero C, Moragues C, Nolla JM, Narváez JA, et al. A thermographic disease activity index for remote assessment of rheumatoid arthritis. *RMD Open* 2022;8:e002615.
7. Aletaha D, Neogi T, Silman AJ, Funovits J, Felson DT, Bingham CO 3rd, et al. 2010 rheumatoid arthritis classification criteria: an American College of Rheumatology/European League Against Rheumatism collaborative initiative. *Ann Rheum Dis* 2010;69:1580–8.
8. Backhaus M, Burmester GR, Gerber T, Grassi W, Machold KP, Swen WA, et al. Guidelines for musculoskeletal ultrasound in rheumatology. *Ann Rheum Dis* 2001;60:641–9.
9. D'Agostino MA, Terslev L, Aegerter P, Backhaus M, Balint P, Bruyn GA, et al. Scoring ultrasound synovitis in rheumatoid arthritis: a EULAR-OMERACT ultrasound taskforce-Part 1: definition and development of a standardised, consensus-based scoring system. *RMD Open* 2017;3:e000428.
10. Chojnowski M. Infrared thermal imaging in connective tissue diseases. *Reumatologia* 2017;55:38–43.
11. Tan YK, Hong C, Li H, Allen JC Jr, Thumboo J. Thermography in rheumatoid arthritis: a comparison with ultrasonography and clinical joint assessment. *Clin Radiol* 2020;75:963.e17–963.e22.
12. de Jesus SFC, Bassi-Dibai D, Pontes-Silva A, da Silva de Araujo A, de Freitas Faria Silva S, Veneroso CE, et al. Construct validity and reliability of the 2-Minute Step Test (2MST) in individuals with low back pain. *BMC Musculoskeletal Disord* 2022;23:1062.
13. Han J, Geng Y, Deng X, Zhang Z. Subclinical synovitis assessed by ultrasound predicts flare and progressive bone erosion in rheumatoid arthritis patients with clinical remission: a systematic review and metaanalysis. *J Rheumatol* 2016;43:2010–8.
14. Morales-Ivorra I, Taverner D, Codina O, Castell S, Fischer P, Onken D, et al. External validation of the machine learning-based thermographic indices for rheumatoid arthritis: a prospective longitudinal study. *Diagnostics (Basel)* 2024;14:1394.
15. Triantafyllias K, Clasen M, De Blasi M, Berres M, Nikolodimos E, Schwarting A. Performance of a novel high-resolution infrared thermography marker in detecting and assessing joint inflammation: a comparison with joint ultrasound. *Clin Exp Rheumatol* 2024;42:1802–11.