Chronic Diseases Prevention Review 9 (2019) 34-40

Available at http:// www.cancercellresearch.org ISSN 2158-0820

The association between knee temperature and pain in patients with knee osteoarthritis: a pilot study

Qilin Shi, Lin Wang, Xiao Chu, Tieshan Li*, Xiaojuan Shi, Mengmeng Xu, Lixiao Cheng

Qingdao University Medical College, Qingdao 266000, China

Abstract: To evaluate the pain and dysfunction of knee osteoarthritis by infrared thermal imaging. A total of 84 subjects were included in this study (24 control group and 60 symptomatic group). Symptomatic group cases were divided into mild group (33 cases) and moderately severe group (25 cases) according to visual analogue scale (VAS). Pain and dysfunction were assessed by visual analogue scale (VAS) and the Western Ontario and McMaster University of orthopedic index (WOMAC). Infrared imaging was performed using the SP-9000 Infrared Diagnostic System Line Thermal Imaging Diagnostic System. The SP-9000 medical infrared thermal image was used to conduct infrared thermal imaging examination on the day of the test and 4 weeks after the test. The upper medial temperature was moderately correlated with pain (rs =0.469, P=0.001), and also with the western Ontario and McMaster university of orthopedic index (rs=0.520, P=0.001). Patella temperature was weakly correlated with pain (rs =0.331, P=0.010), and the patella temperature of the knee joint was weakly correlated with the WOMAC index (rs=0.375, P=0.003). Two infrared thermal imaging examinations of the knee suggested the reliability and repeatably of the knee assessed by infrared thermal imaging (0.66-0.89). There is a correlation between infrared thermography and the severity of knee osteoarthritis pain.

Keywords: Osteoarthritis; Knee; thermography; Knee arthritis

Received 25 January 2019, Revised 17 March 2019, Accepted 18 March 2019

*Corresponding Author: Tieshan Li, tieshanl@126.com

1. Introduction

Knee osteoarthritis (KOA) is a joint disease in the elderly, and the pain is the main reason for patients to seek medical care[1]. The pain of KOA is caused by a variety of causes, and the relationship between pain and changes in knee anatomy is not clear. Early magnetic resonance imaging and X-ray imaging studies of the relationship between the degree of pathological changes in anatomical structures and KOA pain and dysfunction are inconsistent[2]. The mechanism of KOA pain remains unclear. The exploration of the relationship between KOA pain and anatomical lesions prompted by imaging examinations is ongoing. In recent years, with the advancement of musculoskeletal ultrasonography, the research on the relationship between anatomical lesions and KOA pain using ultrasound has been growing year by year. Some studies have used knee joint multi-site ultrasound scanning to find the knee anatomical structure changes. It is a correlation between pain[1,3]. Study found that the cartilage degeneration changes detected by ultrasound are related to clinical symptoms and function[4,5]. Malas[3] did not observe WOMAC in symptomatic group. A positive correlation between the osteoarthritis index and the severity of cartilage degradation has been found. Therefore, the relationship between structural lesions and pain is inconclusive and has yet to be explored.

X-ray, CT, MR and ultrasound can provide information on knee anatomical lesions, which are structural imaging studies, but do not take into account changes in tissue and organ physiology and function. Infrared thermography provides the body's thermal, metabolic and vascular changes by measuring changes in the surface temperature of the body, reflecting changes in the physiological and functional aspects of the tissue, and is a functional imaging examination. The skin temperature of the healthy human body is symmetrically distributed[6]. Asymmetry in skin temperature distribution suggests an abnormality in the body. Therefore, infrared thermography can be invoked as a research tool for studying thermoregulation and temperature-related pain disorders. Previous studies have explored from anatomical images, and there have been few studies that take account of the degree of pain in KOA from a physiological and functional perspective. Infrared thermography has served as a new functional imaging test to evaluate KOA pain. This study used digital infrared thermography to observe KOA patients in order to explore the temperature changes in different regions of the knee detected by infrared thermography are related to the pain level of KOA patients and the feasibility of infrared thermography to assess the severity of KOA pain.

2. Methods

2.1. Inclusion and exclusion criteria

This study selected 84 patients with KOA who were diagnosed by the Department of Rehabilitation of the Affiliated Hospital of Qingdao University from November 2017 to October 2018.

Diagnostic criteria: According to the American College of Rheumatology for the diagnosis of knee osteoarthritis.

Exclusion criteria: (1) history of knee surgery; (2) severe primary disease and mental illness with cardiovascular, hepatic, renal, and hematopoietic systems; (3) other diseases affecting knee joints, such as knee joint tumors, Rheumatoid arthritis, gout, etc.; (4) pregnant or lactating women; (5) severe arterial stenosis of the lower extremities.

According to whether there is pain, it is structured in asymptomatic group and symptomatic group, including 24 in the asymptomatic group. Depending on the X-ray Kellgren-Lawrance classification [7], the heavier side of the structural damage is used as the observation side. If the joints are graded consistently, the left knee joint is selected as the observation side. There were 60 patients in the symptom group, including 55 patients with bilateral KOA. We utilized the heavier side of the pain as the observation index. If the pain of the bilateral knee joints was the same ones, the left knee joint was used as the observation side.

2.2. Subjective evaluation indicators

2.2.1. Pain assessment

Maxwell[8] visual analogue scales (VAS), with a scale of 0-10cm, divided into 10 grades, the greater the number, the greater the intensity of pain. The method is attributed to the patient before use, and the position of the scale of the degree of conscious pain is indicated by the patient. Patients in the symptomatic group were divided into a mild group of 33 (VAS: 1cm-4cm) and a moderately severe group of 27 (VAS: 5cm-10cm) according to the VAS score.

2.2.2. Assessment of KOA function

The WOMAC Osteoarthritis Scoring system proposed by researchers at Belly et al. [9] was used to assess the pain, stiffness and function of the knee joint in the past week and to record the total score.

2.3. Infrared thermography inspections

2.3.1. Equipment and environmental requirements

Infrared thermography was performed using a medical infrared thermal imager (Spectrum 9000-MB Series; United Integrated Service Co. Ltd, Taipei Hsien) with a temperature resolution of 0.05 K, a temperature range of 10 to 40℃, and a minimum analytical temperature difference of 0.01℃. The inspection is carried out in a standardized environment. The ambient temperature and humidity are controlled at 25 ℃ ± 1 ℃ and 50% ± 10%, respectively. The ambient temperature is monitored in real time using black body to ensure the accuracy of temperature calculation [10], and the ambient temperature is substandard. The datum is discarded.

2.3.2. Checking precautions and methods

Infrared thermography was carried out twice on the day of the test and 4 weeks after the test. 72 hours before the examination, there was no topical drug or applicator in the knee joint. The subject's body part did not approach or contact any heat source or cold source. The subject was away from the air convection source. These precautions were taken to minimize the probable temperature. Before the test, the subjects were in the test room, and the legs were set out for 20 min to ensure a relatively stable balance of the human thermophysiological state. The subject took the standing position and adjusted the height of the camera parallel to the knee joint of the subject, and the focal length was set to 72 cm. Two infrared imaging acquisitions were performed on the front of the patient's knee, with an image interval of 5 s. A 1 dollar coin was placed in the center of the tibia of the test side as an anatomical marker, and was photographed 5 times in succession, discarded for the first time, and the average temperature was taken for the remaining 4 times. After the acquisition is expected to be completed, the collected images are stored, edited, temperature measured and image analyzed.

2.3.3. Image analysis

Image analysis was performed using an thermal infrared imaging instrument's own program. Using the marker image as a guide, extract the temperature of the 5 regions of interest (upper medial, superior lateral, tibia, lower medial and lower lateral, Figure 1), and then extract 1 cm of the lower third of the calf tibia of the same individual. As a reference temperature (Figure 2), the five regions of interest were respectively subtracted from the reference temperature, and the results were statistically analyzed.

2.4. Statistical analysis

Statistical analysis was performed using SPSS 23.0 software. Comparing the age and BMI used the rank sum test. The knee temperature of the groups was compared by independent sample t test. Evaluate the reliability and repeatability of the two infrared thermography measurements using the intra-group correlation coefficient (ICC). Correlation analysis was performed on the temperature of the five regions with the VAS and WOMAC osteoarthritis index using the spearman rank correlation.

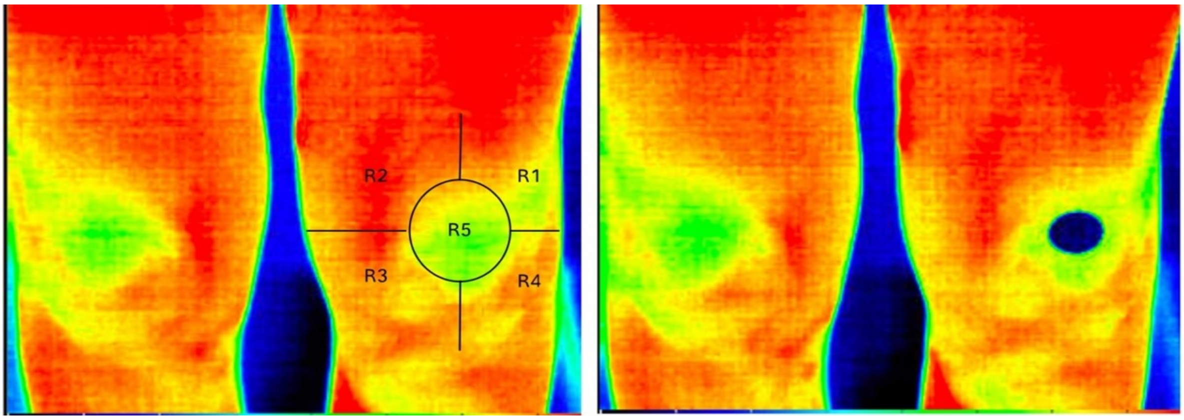

Figure 1. Infrared thermography image analysis. Determining the position of the tibia allows for better identification of regions of interest on the infrared thermography image. Two images obtained using infrared thermography, one uncastrated patella position (shown on the left) and the other using a 1-dollar coin to calibrate the position of the tibia, which appears as a black circle in the infrared thermography image (shown on the right) . The method of dividing the region of interest of the knee joint by Chao Jin[11] was used only for division. R5-patella; R2-upper medial; R1-upper lateral; R3-lower medial; R4-lower lateral.

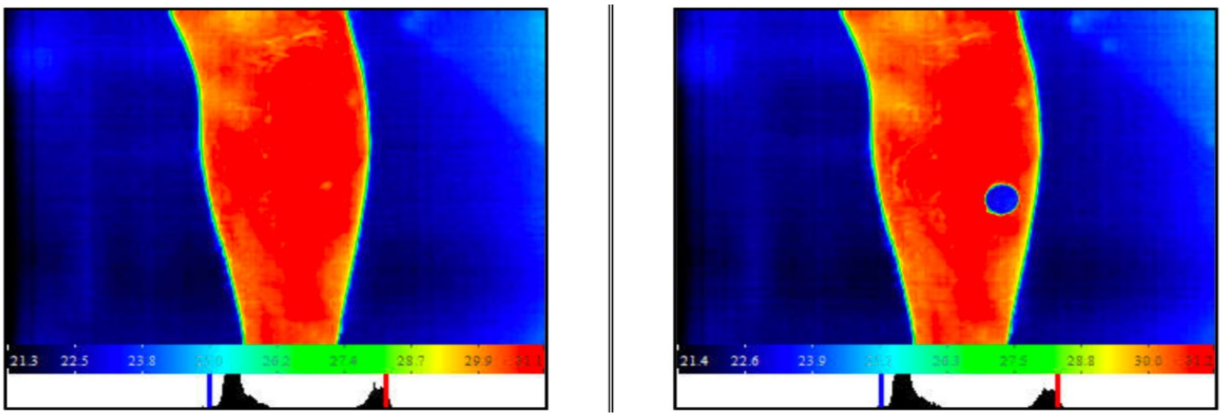

Figure 2. Extracting the reference temperature. One of the lower third of the calf tibia of the same individual was extracted as a reference temperature. Two images were obtained using infrared thermography: one uncalibrated 1 cm position outside the lower third of the calf tibia (shown on the left) and the other using a 1-dollar coin to calibrate the 1 cm position outside the lower third of the tibia. The image appears as a black circle in the infrared thermography image (shown on the right).

3. Results

3.1. Basic patient status

Table 1. Basic patient status

n	Mild group	Moderately severe group group	Asymptomatic control group
	F: 30 M: 3	F: 24 M:3	F: 21 M:3
Age	62.09 ± 6.14	65.00 ± 4.35	61.06 ± 4.04
BMI	23.71 ± 1.71	26.48 ± 2.26	25.47 ± 1.54

A total of 33 patients in the mild group, 27 in the moderate to severe group, and 24 in the asymptomatic control group were established. There was no significant difference in age and BMI between the three groups (P>0.05).

3.2. Infrared thermography analysis

3.2.1. Analysis of the average temperature of the knee joint (Table 2)

Table 2. Knee temperature analysis

Area	Asymptomatic control group temperature ($\bar{x} \pm s$)	Mild group temperature ($\bar{x} \pm s$)	Moderately severe group temperature ($\bar{x} \pm s$)
Upper medial	-1.17 ± 1.03	-0.23 ± 1.86&	1.34 ± 1.85#、*
Upper lateral	-0.67 ± 0.90	-0.74 ± 1.53	0.21 ± 1.96#、*
Patellar	-2.71 ± 0.86	-2.26 ± 1.26	-0.99 ± 2.07#、*
Lower medial	-0.59 ± 1.04	-0.39 ± 1.60	0.13 ± 2.13
Lower lateral	-0.18 ± 1.53	-0.38 ± 1.49	0.47 ± 2.02

Compared with the moderate to severe group (#), the upper medial temperature, upper lateral temperature and Patellar temperature differences were statistically significant (P<0.05), and the asymptomatic control group was compared with the moderately severe group (*), upper medial and superior lateral There was a statistically significant difference in the temperature of the tibia (P<0.05). The asymptomatic control group was compared with the mild group and the difference in the upper medial temperature was statistically significant.

3.2.2. Reliability and repeatability detection of infrared thermal imaging (Table 3)

Table 3. Reliability and repeatability detection of infrared thermal imaging

Area	Average temperature of the day of the test（ $\bar{x} \pm s$ ）	Average temperature after 4 weeks of test（ $\bar{x} \pm s$ ）	ICC
Upper medial	0.07 ± 1.92	-0.70 ± 1.78	0.66
Upper lateral	-0.42 ± 1.59	-0.44 ± 1.68	0.85
Patellar	-1.98 ± 1.63	-1.74 ± 1.71	0.81
Lower medial	-0.28 ± 1.67	-0.23 ± 1.68	0.89
Lower lateral	-0.05 ± 1.71	-0.13 ± 1.77	0.86

ICC, representing the correlation coefficient within the group

The reliability and repeatability of each area of the infrared thermography were good (0.66-0.89).

3.2.3. Correlation between infrared thermography and pain in symptomatic groups (Table 4)

Table 4. Related detection of symptomatic infrared thermography and VAS, WOMAC

Area	VAS	WOMAC
Upper medial	0.469(0.001)	0.520(0.001)
Upper lateral	0.150(0.254)	0.293(0.038)
Patellar	0.331(0.010)	0.375(0.003)
Lower medial	0.007(0.956)	0.098(0.457)
Lower lateral	0.317(0.061)	0.352(0.055)

The medial temperature of the knee was moderately correlated with pain (rs = 0.469, P = 0.001), and the medial temperature was moderately correlated with the WOMAC osteoarthritis index (rs = 0.520, P = 0.001). The temperature of the tibia was weakly correlated with pain (rs = 0.331, P = 0.010), the temperature of the tibia was weakly correlated with the WOMAC osteoarthritis index (rs = 0.375, P = 0.003). (spearman correlation coefficient: 0.00-0.19 is very weak; 0.20-0.39 is weak; 0.40-0.59 is medium; 0.60-0.79 is strong; 0.80-1.0 is very strong)

4. Discussion

Infrared thermography has a long history of application in musculoskeletal trauma. Albert is the principal investigator to evaluate pain using infrared thermography[12]. Due to the low localization and diagnostic value of infrared thermography, poor stability, lack of specificity of the results. Other shortcomings[13], infrared thermal imaging in the evaluation of pain have been questioned. However, with the improvement of computer-aided methods and equipment, the accuracy of infrared thermal imaging has been greatly improved. The infrared thermal imaging image used in this study has a minimum resolution temperature of 0.01 ℃.

In recent years, infrared thermography has been widely used in temperature-related pain assessment studies. Czaplik[14] used infrared thermography to analyze the relationship between facial expression, tearing and sweating and pain, and found facial expressions and tears. The "heat-related pain index" suggested by sweating is significantly associated with NRS, and the sensitivity of infrared thermography to detect pain can reach more than 75%. Ammer[15] used infrared thermography to observe post-herpetic neuralgia, and found that the thermal asymmetry of patients with acute or chronic herpes zoster. The skin temperature of patients with early post-herpetic neuralgia increased. Carlos[16] used infrared thermography to assess the correlation between skin temperature and cervical vertebra motion range, electromyography activity and pain in patients with chronic neck pain in 40 patients who have chronic neck pain and trapezius muscle myofascial trigger points. The results showed that the range of cervical vertebra activity was reduced in patients with chronic neck pain with lower skin temperature at the triggering point of the trapezius muscle myofascial fascia. Therefore, infrared thermography is a reliable functional imaging method that can be used to assess pain-related diseases.

This study found that in the three groups of subjects, the median temperature in the moderate to severe group was higher in the mild group and the asymptomatic group. The upper medial temperature in the mild group was higher than in the asymptomatic group, and the upper part of the knee in the symptom group. The regional mean temperature was moderately correlated with pain and moderately correlated with the WOMAC Osteoarthritis Index. Therefore, changes in the medial and posterior temperature of the knee can be used to assess knee pain and dysfunction. The pain of KOA often occurs in the medial part of the knee[18], which may be caused by articular cartilage degeneration, osteophyte formation and meniscus compression of KOA patients. The inflammation drives synovial angiogenesis through the activation of macrophages, and release of vascular endothelial growth factor, β-neural growth factor and neuropeptides promote the growth of blood vessels and nerve. These new sensory nerve accompany the growth of new blood vessels, eventually reaching the articular cartilage, osteophytes and meniscus. These senses the peripheral nerve, causing pain inside the knee joint[19,20], and nerve stimulation affects local blood circulation, resulting in changes in temperature. Therefore, the upper medial temperature change may be an important part of the severity of KOA pain.

The study also found that the tibia temperature of the knee joint in the moderate to severe group was higher than that in the mild group and the asymptomatic group. There was a weak correlation between the temperature of the tibia and the pain in the symptom group, and weakly correlated with the WOMAC osteoarthritis index. The humerus is the area that reflects the temperature change inside the knee[21] and is associated with synovial blood flow[22]. Therefore, the relationship between the temperature of the tibia and the pain may be due to the softening of the tibia[23], causing changes in the blood flow of the synovial membrane, resulting in temperature changes. Because the degree of correlation is low, the temperature change of the tibia cannot be used as an indicator of KOA pain. The reason for the lower degree of correlation may be related to the small number of samples, and further expansion of the sample size is needed for observation.

In addition, through the intra-group correlation coefficient analysis on the day of the test and after 4 weeks, we proved that as a means of functional imaging, infrared thermography evaluates KOA with credibility and repeatability.

Infrared thermography is rarely used in KOA pain studies. Previous studies on KOA infrared thermography are still inconsistent. Ahlem[13] observed the relationship between skin temperature and pain in 10 KOA patients and 12 healthy people. Joint skin temperature increases with increasing pain and can be used to assess pain levels. Kwon[24] used infrared thermography to evaluate the efficacy of acupuncture treatment. It was found that acupuncture treatment of KOA patients can reduce skin temperature before treatment and relieve pain. Other studies have suggested that changes in skin temperature cannot be used to assess pain. Tsai[21] used a YSI Model 4000 Dual Channel Display Telethermometer to assess the pain of 12 well-cogniated KOA elderly patients and found that the skin temperature was not associated with pain. The results are inconsistent with us. The reasons may be that (1) the sample size of the study is too small, lack of sufficient representativeness, and it is difficult to ensure the accuracy and reliability of the results; (2) the instruments used are different, and the detection range of the instruments used only Can cover a surface area of 50 mm^2. We use a medical infrared thermal imager that determines the size of the region of interest based on the needs of the clinician and records the skin surface temperature in real time[25]; (3) Tsai et al. did not mention ambient temperature control in the article, which may affect the accuracy of the results. In this study. We used the black body to monitor and feedback the ambient temperature in real time. If there is a large fluctuation in the ambient temperature, the ambient temperature will be adjusted at any time to control the temperature within the range of 25℃±1℃, thus avoiding infrared heat. Imaging inspection is susceptible to environmental temperature, greatly improving the reliability of temperature measurement. Due to slight differences in individual anatomy, in order to more accurately locate the position of the humerus, we used a 1 dollar coin to determine the center of the humerus, which improved the accuracy of the positioning of the temperature assessment process.

5. Conclusion

This study found that there is a correlation between the upper medial temperature and pain in KOA patients, suggesting that the upper medial temperature can be used as an indicator for clinical assessment of KOA pain. Due to the small sample size of this study, a larger sample study is needed in the future to further clarify the infrared. The value of thermal imaging in KOA pain assessment.

References

[1] Jana Podlipská, Koski J M, Päivi K, et al. Structure-symptom relationship with wide-area ultrasound scanning of knee osteoarthritis[J]. Sci Rep, 2017, 7:44470.

[2] Dieppe P A. Relationship between symptoms and structural change in osteoarthritis: what are the important targets for therapy?[J]. Journal of Rheumatology, 2005, 32(6):1147.

[3] Malas FÜ, Kara M, Kaymak B, et al. Ultrasonographic evaluation in symptomatic knee osteoarthritis: clinical and radiological correlation [J]. International Journal of Rheumatic Diseases, 2014, 17(5):536-540.

[4] Chen Y J, Chen C H, Wang C L, et al. Association between the Severity of Femoral Condylar Cartilage Erosion Related to Knee Osteoarthritis by Ultrasonographic Evaluation and the Clinical Symptoms and Functions[J]. Archives of Physical Medicine & Rehabilitation, 2015, 96(5):837-844.

[5] Razek A A, Elbasyouni S R. Ultrasound of knee osteoarthritis: interobserver agreement and correlation with Western Ontario and McMaster Universities Osteoarthritis.[J]. Clinical Rheumatology, 2016, 35(4):997-1001.

[6] 3Rd W T, Fast T B, Livingston W A. Human body temperature[J]. J Indianap Dist Dent Soc, 1971, 3:22-23.

[7] Hunter D J, Mcdougall J J, Keefe F J. The symptoms of OA and the genesis of pain[J]. Rheumatic Diseases Clinics of North America, 2008, 34(3):623.

[8] Maxwell C. Sensitivity and accuracy of the visual analogue scale: a psycho-physical classroom experiment.[J]. British Journal of Clinical Pharmacology, 2012, 6(1):15-24.

[9] Bellamy N. Pain assessment in osteoarthritis: experience with the WOMAC osteoarthritis index[J]. Seminars in Arthritis & Rheumatism, 1989, 18(4):14-17.

[10] Chang T C, Hsiao Y L, Liao S L. Application of digital infrared thermal imaging in determining inflammatory state and follow-up effect of methylprednisolone pulse therapy in patients with Graves' ophthalmopathy[J]. 2008, 246(1):45-49.

[11] Jin C, Yang Y, Xue Z, et al. Clinical research of knee osteoarthritis screening based on infrared thermography[J]. Beijing Biomedical Engineering, 2014, 8(6):169.

[12] Albert S M. Thermography in orthopedics[J]. Annals of the New York Academy of Sciences, 2010, 121(1):157-170.

[13] Arfaoui A, Bouzid M A, Pron, H, et al. Application of Infrared Thermography as a Diagnostic Tool of Knee Osteoarthritis[J]. Journal of Thermal Science & Technology, 2012, 7(7):227-235.

[14] Czaplik M, Hochhausen N, Dohmeier H, et al. Development of a "Thermal-Associated Pain Index" score using infrared-thermography for objective pain assessment.[C]// International Conference of the IEEE Engineering in Medicine & Biology Society. IEEE, 2017.

[15] Ammer K, Schartelmueller T, Melnizky P. Thermal imaging in acute herpes zoster or post-zoster neuralgia.[J]. Skin Research and Technology, 2010, 7(4):219-222.

[16] Girasol C E, Dibaifilho A V, De A O, et al. Correlation Between Skin Temperature Over Myofascial Trigger Points in the Upper Trapezius Muscle and Range of Motion, Electromyographic Activity, and Pain in Chronic Neck Pain Patients.[J]. Journal of Manipulative & Physiological Therapeutics, 2018.

[17] Razek A A, Elbasyouni S R. Ultrasound of knee osteoarthritis: interobserver agreement and correlation with Western Ontario and McMaster Universities Osteoarthritis.[J]. Clinical Rheumatology, 2016, 35(4):997-1001.

[18] Jana P, Koski J M, Päivi K, et al. Structure-symptom relationship with wide-area ultrasound scanning of knee osteoarthritis[J]. Sci Rep, 2017, 7:44470.

[19] Mapp P I, Walsh D A. Mechanisms and targets of angiogenesis and nerve growth in osteoarthritis[J]. Nature Reviews Rheumatology, 2012, 8(7):390-398.

[20] Pao-Feng Tsai, Richards K, Tatom I. The association between knee temperature and pain in elders with osteoarthritis of the knee: a pilot study[J]. Journal of Advanced Nursing, 2003, 42(4):9.

[21] Osh J A, Lindsay D J, Davies E R, et al. The technetium scintigram as an indicator of syovial vascularity in rheumatoid arthritis: its comparison with the results of temperature measurement.[J]. Annals of the Rheumatic Diseases, 1970, 29(6):691.

[22] Singer B J, Silbert B I, Silbert P L, et al. The Role of Botulinum Toxin Type A in the Clinical Management of Refractory Anterior Knee Pain.[J]. Toxins, 2015, 7(9):3388-3404.

[23] Kwon Y B, Kim J H, Yoon J H, et al. The Analgesic Efficacy of Bee Venom Acupuncture for Knee Osteoarthritis: A Comparative Study with Needle Acupuncture[J]. The American Journal of Chinese Medicine: An International Journal of Comparative Medicine East and West, 2001, 29(02):1.

[24] Huang C L, Wu Y W, Hwang C L, et al. The application of infrared thermography in evaluation of patients at high risk for lower extremity peripheral arterial disease[J]. Journal of Vascular Surgery, 2011, 54(4):1074-1080.