

Differential knee skin temperature following total knee arthroplasty and its relationship with serum indices and outcome: A prospective study

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Abstract

Objectives: To monitor knee skin temperature changes for 12 months following total knee arthroplasty (TKA) and identify potential reasons for any differences in skin temperature and to investigate if there is a relationship between the differential temperature and clinical outcome.

Methods: Patients who attended for a unilateral TKA due to primary osteoarthritis between August 2012 and August 2014 were eligible for this prospective study. The skin temperature of both knees was monitored preoperatively and postoperatively using an infrared thermometer. Serum indices and Hospital for Special Surgery (HSS) knee scores were assessed.

Results: Thirty-nine patients were involved in the study. The skin temperature of both knees as well as the differential temperature increased following TKA. Serum haemoglobin, haematocrit and days from surgery showed inverse correlations with the differential temperature, while body mass index and American Society of Anesthesiologists scores showed positive correlations. There was a strong inverse correlation between the differential temperature and HSS. score.

Conclusions: Differential knee skin temperature elevation 12 months post-TKA may be a normal surgical response.

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Keywords

Differential skin temperature, infrared thermometer, total knee arthroplasty, osteoarthritis, periprosthetic joint infection

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Introduction

Total knee replacement or total knee arthroplasty (TKA) is a proven technique for the treatment of severe knee osteoarthritis (OA) and it has a 99.0% and 92.4% implant survivorship at 10 years and 15 years, respectively.^{1,2} The procedure should improve physical function, alleviate pain and promote quality of life, but many studies show that patients' self-reported satisfaction varies from 70.0% to 90.0%.³⁻⁶ We have observed in our clinic that skin temperature of the operated knee can be elevated for up to 6 months post-operatively in patients who have been treated by TKA for primary OA. Although no tenderness or swelling has been observed in these patients, concerns have been raised among patients and surgeons about potential postoperative infections that can be a major and costly complication⁷ and have an incidence of 0.2–2%.⁸⁻¹⁰

Clearly, it is important to differentiate between an infectious and noninfectious response in patients who have had a TKA and an increase in knee skin temperature. Therefore, this prospective study was undertaken to monitor knee skin temperature changes in both knees for 12 months following TKA and to identify potential reasons for any differences in skin temperature and to investigate if there is a relationship between the differential temperature and clinical outcome.

Patients and methods

Patient population

Patients who attended the out-patient department of The First Affiliated Hospital

of Guangzhou University of Traditional Chinese Medicine, Guangzhou City, Guangdong Province, China for a unilateral TKA due to primary OA between August 2012 and August 2014 were eligible for inclusion in this prospective study. Prior to the procedure, all patients had chest X-rays taken and blood and urine analysed to preclude any insidious lung and/or urinary infections. Inclusion criteria were: (i) men and women between the ages of 50 and 80 years; (ii) no evidence of any lung and/or urinary infection; (iii) available to complete the study. Exclusion criteria were: (i) infection of any type; (ii) rheumatoid arthritis; (iii) severe underlying disease that may have influenced the body temperature as well as knee skin temperature (e.g. renal and heart failure, stroke sequela, tumour, anaemia, liver cirrhosis, hyperthyroidism, autoimmune disease, diabetes mellitus); (iv) long-term glucocorticoid usage; (v) an infection less than 6 months before surgery.

This study was approved by the Ethics Committee of Guangzhou University of Traditional Chinese Medicine, Guangzhou City, Guangdong Province, China (no. 2012027) and it complied with the Declaration of Helsinki. All patients provided written informed consent. In addition, this study was registered on the Chinese Clinical Trial Registry (<http://www.chictr.org>; registration no. ChiCTR-ONRC-13003785).

Study methodology

Patients' demographic data, including sex, age, height, weight, body mass index (BMI) and American Society of Anesthesiologists (ASA) classification (1, healthy to 5, moribund) were

recorded preoperatively.¹¹ In addition, the severity of both knees was graded using the Kellgren–Lawrence (K–L) OA classification system (0, normal to 4, severe).¹² The Hospital for Special Surgery (HSS) knee score (0 to 100) was used to quantify the function of the operated knee preoperatively and at 12 months postoperatively.¹³

A portable infrared thermometer (Optris GmbH, Berlin, Germany) was used to measure knee skin temperature. The thermometer had a detection range between 30.0°C and 50.0°C, high accuracy and stability with a measurement error of no more than $\pm 0.4^\circ\text{C}$ and a repetitive accuracy of 0.2°C. The thermometer had a response time of 300 ms and so temperatures could be read instantly. It was able to work in ambient temperatures from 0°C to 50.0°C and between 10.0% to 95.0% ambient humidity.

Skin knee temperature was measured by one of the investigators (P.D.) on the day before surgery and thereafter at 1, 3, 5, 7, 15, 30, 90, 180, and 360 days postoperatively. For the measurements, patients were seated with both knees in 90 degrees flexion in a controlled environment of $20.0 \pm 1.0^\circ\text{C}$ and $50.0\% \pm 10.0\%$ humidity. They were instructed to leave both lower limbs exposed and were acclimatized to the environment for 15 to 20 min before temperature assessments took place. Knee skin temperature was measured between 09.00 h to 12.00 h and between 14.00 h to 17.00 h. Four locations (i.e. superolateral, superomedial, inferiorlateral and inferiormedial border of the patellar) were used and the infrared thermometer was positioned 0.5 cm from these areas (Figure 1). The approximate intra-articular knee temperature was taken as a



Figure 1. This representative patient underwent total knee arthroplasty 1 month previously. For the skin knee temperature measurements, patients were seated with both knees in 90 degrees flexion in a controlled environment of $20.0 \pm 1.0^\circ\text{C}$ and $50.0\% \pm 10.0\%$ humidity. Skin temperature was measured using an infrared thermometer and for this patient showed a 3.1°C temperature difference between the operated and contralateral knees.

mean value of these four areas. The differential temperature (i.e. temperature of the operated knee minus the temperature of the contralateral knee) was graded as mild ($< 1.0^{\circ}\text{C}$), moderate ($1.0\text{--}3.0^{\circ}\text{C}$) or severe elevation ($> 3.0^{\circ}\text{C}$).

A 3-ml sample of venous blood was collected and stored at room temperature prior to analysis. Serum indices (i.e. erythrocyte sedimentation rate [ESR], C-reactive protein [CRP], white blood cells [WBC], haemoglobin [HGB] and haematocrit [HCT]) were assessed pre- and postoperatively at each clinic visit using routine biochemistry laboratory methods.

Statistical analyses

No formal sample size estimations were made but the study planned to recruit at least 30 patients. Student's *t*-test was used to compare the temperature of both knees at each clinic visit. No allowance was made for multiple testing. Differential temperatures across visits and HSS scores were analysed using one-way analysis of variance. The relationship between the variables was assessed using Pearson's correlation coefficient and selected variables from the simple regression analysis ($P < 0.1$) were entered into a multivariate linear regression model.

All statistical analyses were performed using the SPSS[®] statistical package, version 18.0 (SPSS Inc., Chicago, IL, USA) for Windows[®]. A *P*-value < 0.05 was considered statistically significant.

Results

Thirty-nine patients were included in the study (4 men and 35 women) with a mean \pm SD age of 67.2 ± 9.0 years (range, 50 to 85 years), mean \pm SD height 159.7 ± 5.0 cm (range, 152 to 173 cm), mean \pm SD weight 58.4 ± 5.2 kg (range, 50.0 to 73.0 kg) and mean \pm SD BMI 22.8 ± 1.3 kg/m² (range, 19.78 to 25.30 kg/m²). All operated

knees were graded as K–L stage 4 (i.e. severe OA). All patients recovered from the surgery without complications and no progressive symptoms on the contralateral knees were reported at the 12-month follow-up visit.

Pre- and postoperative skin temperature of both knees, the differential skin temperature and serum indices are shown in Table 1. The skin temperature of both the operated and contralateral knees increased following surgery and values were at their highest on Day 5. With the exception of the preoperative visit, the differences between the skin temperatures of both knees were statistically significant at each visit ($P < 0.01$). For the operated knees, the skin temperature only returned to preoperative values at 12 months, whereas for the contralateral knees, the skin temperature was approximately at preoperative values by Day 15 (Figure 2a). By comparison with preoperative values, the difference in skin temperatures between the two knees was greatest at Day 7 and was still higher than the baseline differential at the 12-month follow-up visit ($P = 0.01$) (Figure 2b). The knee skin temperature and differential temperature were highest in the inferiomedial area of knee compared with other areas (data not shown).

Serum concentrations of HGB and HCT fell to their lowest levels at Days 3 and 5 and then gradually returned back to preoperative levels by Days 90 to 180 (Table 1). Levels of WBC increased sharply at Day 1 and returned gradually to preoperative values by Day 30. Concentrations of ESR and CRP peaked at Day 3, and while CRP returned to preoperative levels by Day 30, ESR did not return to preoperative levels until Day 90 (Figure 3).

The skin temperatures of both knees and the differential temperature were inversely correlated with serum concentrations of HGB, HCT and days from surgery ($P < 0.001$) (Table 2). In addition, the skin temperatures for the operated and

Table 1. Values of knee skin temperature and serum indices before and for 12 months following total knee arthroplasty (TKA) ($n = 39$).

Independent variable	Postoperative time-points											
	Preop	1 day	3 days	5 days	7 days	15 days	30 days	90 days	180 days	360 days		
Operated knee, °C*	32.6 ± 1.6	34.7 ± 1.6	35.3 ± 1.4	36.1 ± 0.9	35.3 ± 0.9	34.2 ± 1.1	35.6 ± 0.8	34.2 ± 0.9	33.3 ± 1.2	32.6 ± 1.4		
Contralateral knee, °C*	32.0 ± 1.5	33.7 ± 1.4	33.6 ± 1.5	33.8 ± 1.4	32.9 ± 1.2	32.0 ± 1.2	33.4 ± 0.9	32.5 ± 1.0	32.0 ± 1.2	31.7 ± 1.3		
Differential, °C	0.5 ± 0.7	1.0 ± 0.7	1.7 ± 1.0	2.3 ± 0.9	2.4 ± 0.9	2.2 ± 1.0	2.3 ± 0.7	1.8 ± 0.7	1.4 ± 0.7	0.9 ± 0.7		
HGB, g/l	128.1 ± 12.1	116.2 ± 12.2	103.5 ± 11.4	103.7 ± 9.7	109.9 ± 8.6	115.5 ± 8.1	121.0 ± 9.9	126.3 ± 9.9	128.3 ± 7.5	131.9 ± 6.6		
HCT, l/l	0.39 ± 0.03	0.35 ± 0.04	0.32 ± 0.04	0.32 ± 0.03	0.33 ± 0.03	0.35 ± 0.03	0.37 ± 0.03	0.39 ± 0.03	0.39 ± 0.03	0.41 ± 0.02		
WBC, × 10 ⁹ /l	6.9 ± 1.8	12.5 ± 6.9	10.6 ± 2.2	9.2 ± 1.6	8.8 ± 1.8	8.8 ± 2.1	7.0 ± 1.4	7.1 ± 1.4	6.8 ± 1.4	5.9 ± 1.0		
ESR, mm/h	21.4 ± 12.4	24.4 ± 19.9	40.3 ± 20.1	39.3 ± 21.1	31.6 ± 16.1	26.3 ± 14.8	24.6 ± 16.2	21.3 ± 16.3	17.4 ± 9.2	14.8 ± 6.6		
CRP, mg/dl	7.1 ± 10.4	26.3 ± 19.0	34.6 ± 21.58	21.4 ± 17.9	14.6 ± 16.5	8.0 ± 3.7	6.7 ± 6.6	4.9 ± 4.8	3.7 ± 2.0	2.4 ± 1.0		

Values are shown as mean ± SD.

*The intra-articular knee temperature was taken as a mean value of four areas (superolateral, superomedial, inferiolateral and inferomedial border of the patellar).

Preop, preoperative time-point; HGB, haemoglobin; HCT, haematocrit; WBC, white blood cells; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein.

contralateral knee were strongly positively correlated with serum WBC, ESR and CRP ($P < 0.001$), but only ESR was significantly associated with differential temperature ($P = 0.008$). Both BMI and ASA score at baseline were significantly correlated with the differential temperature ($P < 0.05$).

Multivariable regression analysis using selective variables from the simple regression, found that for the operated knee skin temperature, BMI, ESR and CRP showed mildly positive correlations ($P < 0.05$), while age showed a strong inverse correlation ($P < 0.001$) (Table 3). For the contralateral knee skin temperature, CRP showed a moderate positive correlation ($P = 0.003$), days from surgery showed a moderate inverse correlation ($P = 0.005$), and age showed a strong inverse correlation ($P < 0.001$). For the differential temperature change, HCT and days from surgery showed mildly inverse correlations ($P < 0.05$) and BMI and ASA scores at baseline showed moderate positive correlations ($P < 0.05$).

The HSS scores from the beginning and end of the study, for patients categorized into three grades of differential temperature elevation (mild, moderate and severe), are shown in Table 4. Analysis of variance showed that the difference in the mean ± SD HSS scores at the preoperative and last follow-up visits for the mild group was significantly higher compared with the moderate ($P = 0.005$) or severe elevation groups ($P = 0.04$). Pearson's correlation coefficient analysis showed a strong inverse correlation between the grade of differential temperature elevation and the HSS score improvement ($r = 0.49$, $P = 0.001$).

Discussion

Although TKA is considered one of the most important medical breakthroughs in the 21st century, there are several complications associated with the surgery that might compromise the clinical outcome.⁸⁻¹⁰ Interestingly,

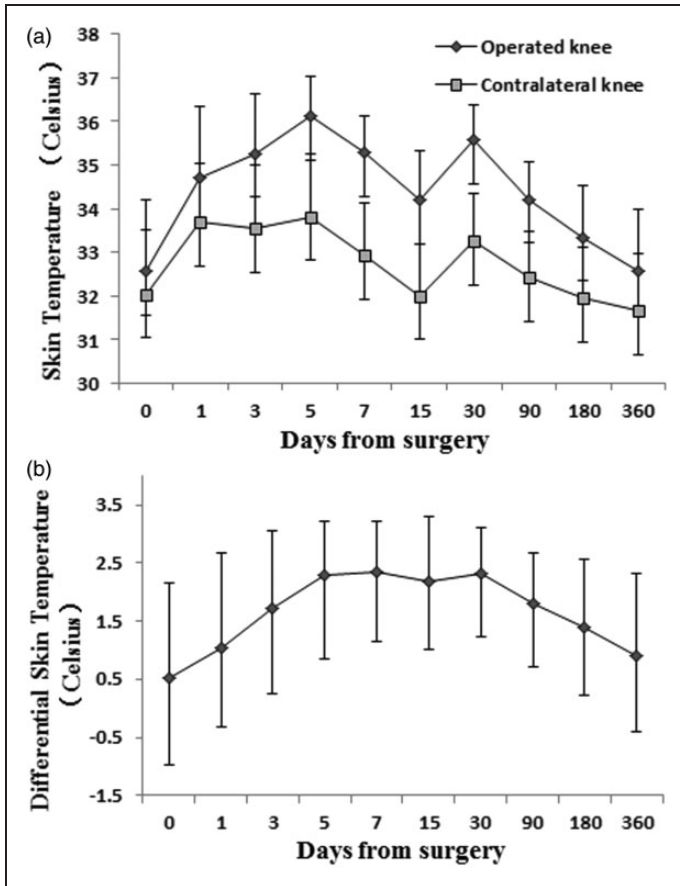


Figure 2. Skin temperature changes for the operated and contralateral knees (a) and the differential between the two knees (b) before and for 12 months following total knee arthroplasty (n = 39).

we have observed in our clinic that patients who have undergone TKA have complained of an increase in skin temperature of the operated knee that could indicate the presence of an infection; indeed, periprosthetic joint infections occur in up to 2% cases.¹⁴ However, following an increase in skin temperature, it is often difficult to differentiate between an infectious and non-infectious response. Therefore, it is important to establish the pattern of knee skin temperatures following TKA and investigate any correlations with other variables that may assist in the diagnosis and treatment of an infection

that would be crucial for a successful surgical outcome.

The measurement of skin temperature requires a consistent ambient temperature. Even though blood flow and heat distribution changes between the morning and afternoon might cause fluctuations in temperature,^{15,16} the infrared thermometer that was used in the present study appeared to be relatively constant. Knee skin temperature quantified through thermography can be used for the assessment joint involvement in inflammatory arthritis and has the advantages of reproducibility, safety and non-

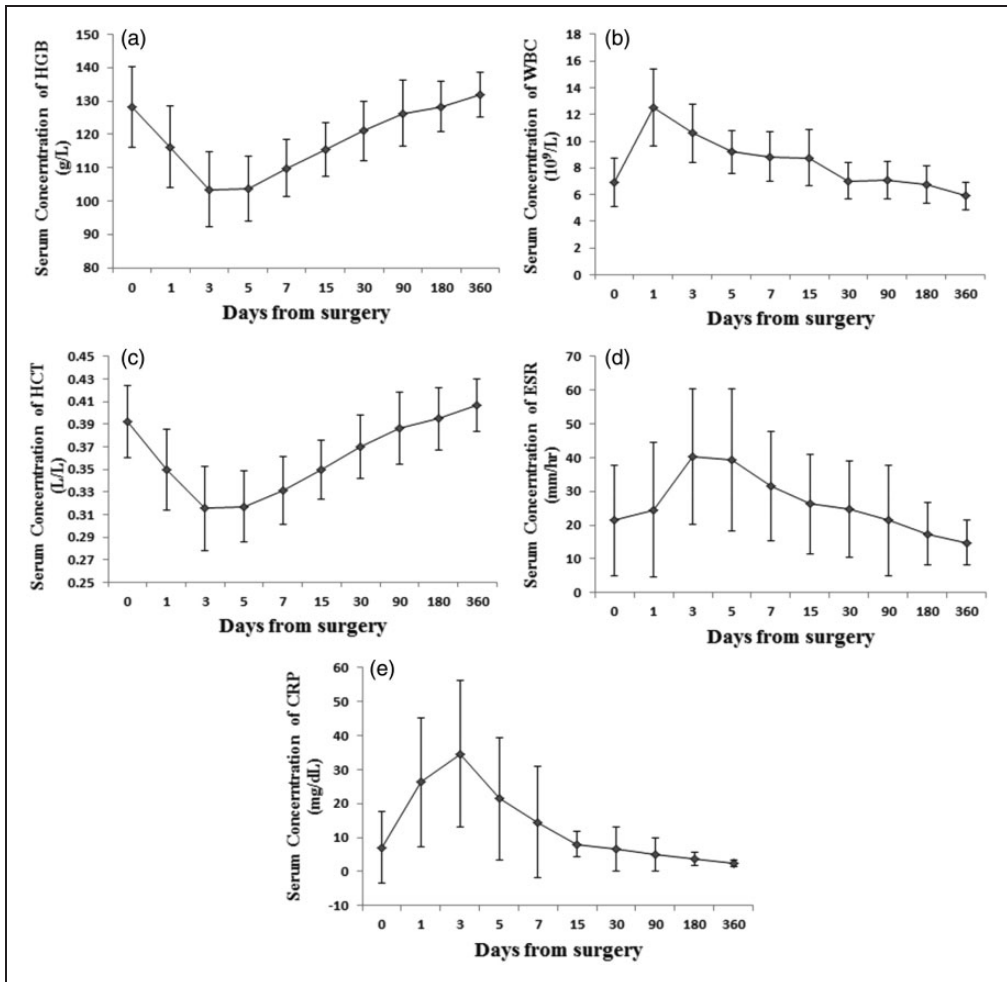


Figure 3. Serum indices taken preoperatively and for up to 12 months postoperatively following total knee arthroplasty ($n = 39$): (a) HGB, haemoglobin; (b) WBC, white blood cells; (c) HCT, haematocrit; (d) ESR, erythrocyte sedimentation rate; (e) CRP, C-reactive protein.

invasiveness.^{17–19} Inflamed joints have been shown to cause an elevation in knee skin temperature,^{20,21} and an increased knee skin temperature measured by digital telethermography has been found to be highly reliable for diagnosing periprosthetic joint infections.²² A sustained increase in the operated knee skin temperature combined with an elevation of ESR and CRP has been suggested as indicating a periprosthetic joint infection.²³

This present study showed that the skin temperature of both the operated and contralateral knee and the differential temperature increased after surgery, which was consistent with a previous report,²⁴ and then returned to preoperative values. A prospective, observational, nonrandomized study, found that healing of the surgical site caused an increase in knee skin temperature of the operated knee, but by 12 months after surgery the temperature was similar to

Table 2. Pearson’s correlation coefficient analysis of the possible correlation between knee skin temperature and other parameters in patients who had undergone total knee arthroplasty (*n* = 39).

Independent variable	Operated knee temperature			Contralateral knee temperature			Differential temperature		
	<i>r</i>	β	Statistical significance	<i>r</i>	β	Statistical significance	<i>r</i>	β	Statistical significance
K–L Classification*	0.039	0.104	NS	0.098	0.227	NS	0.077	-0.123	NS
Age, years*	0.126	-0.024	<i>P</i> = 0.013	0.119	-0.02	<i>P</i> = 0.018	0.036	-0.004	NS
Height, m*	0.036	1.198	NS	0.064	1.901	NS	0.034	-0.702	NS
Weight, kg*	0.071	0.023	NS	0.059	0.017	NS	0.032	0.006	NS
BMI, kg/m ² *	0.088	0.115	NS	0.023	0.026	NS	0.112	0.089	<i>P</i> = 0.026
ASA Score*	0.012	-0.047	NS	0.085	-0.276	NS	0.102	0.229	<i>P</i> = 0.045
HGB, (g/l)	0.379	-0.046	<i>P</i> < 0.001	0.285	-0.03	<i>P</i> < 0.001	0.216	-0.016	<i>P</i> < 0.001
HCT, l/l	0.401	-15.367	<i>P</i> < 0.001	0.28	-9.377	<i>P</i> < 0.001	0.259	-5.99	<i>P</i> < 0.001
WBC, × 10 ⁹ /l	0.304	0.193	<i>P</i> < 0.001	0.296	0.164	<i>P</i> < 0.001	0.076	0.029	NS
ESR, mm/h	0.288	0.027	<i>P</i> < 0.001	0.236	0.019	<i>P</i> < 0.001	0.134	0.008	<i>P</i> = 0.008
CRP, mg/dl	0.346	0.036	<i>P</i> < 0.001	0.332	0.03	<i>P</i> < 0.001	0.092	0.006	NS
POD	0.432	-0.007	<i>P</i> < 0.001	0.332	-0.004	<i>P</i> < 0.001	0.235	-0.002	<i>P</i> < 0.001

*Pre-operative (baseline) values.

r, Pearson’s correlation coefficient; K–L, Kellgren–Lawrence; BMI, body mass index; ASA, American Society of Anesthesiologists; HGB, haemoglobin; HCT, haematocrit; WBC, white blood cells; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; POD, postoperative day; NS, not statistically significant (*P* ≥ 0.05).

Table 3. Multivariable regression analysis of independent predictors of changes in knee skin temperature in patients who had undergone total knee arthroplasty (*n* = 39).

Independent variable	Operated knee temperature		Contralateral knee temperature		Differential temperature	
	β	Statistical significance	β	Statistical significance	β	Statistical significance
K–L Classification*	Excluded		Excluded		Excluded	
Age, years*	-0.04061	<i>P</i> < 0.001	-0.037	<i>P</i> < 0.001	-0.008	NS
Height, m*	Excluded		Excluded		Excluded	
Weight, kg*	Excluded		Excluded		Excluded	
BMI, kg/m ² *	0.141343	<i>P</i> = 0.014	Excluded		0.118	<i>P</i> = 0.003
ASA Score*	Excluded		-0.185	NS	0.311	<i>P</i> = 0.007
HGB, (g/l)	-0.01641	NS	-0.026	NS	0.017	NS
WBC, ×10 ⁹ /l	Excluded		0.045	NS	Excluded	
HCT, l/l	-2.10299	NS	3.671	NS	-8.828	<i>P</i> = 0.023
ESR, mm/h	0.012677	<i>P</i> = 0.013	0.006	NS	0.006	NS
CRP, mg/dl	0.012413	<i>P</i> = 0.026	0.015	<i>P</i> = 0.003	-0.004	NS
POD	0.029341	NS	-0.002	<i>P</i> = 0.005	-0.001	<i>P</i> = 0.012

*Pre-operative (baseline) values.

K–L, Kellgren–Lawrence; BMI, body mass index; ASA, American Society of Anesthesiologists; HGB, haemoglobin; WBC, white blood cells; HCT, haematocrit; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; POD, postoperative day; NS, not statistically significant (*P* ≥ 0.05).

Table 4. Hospital for Special Surgery (HSS) knee scores and differential knee temperatures for patients who had undergone total knee arthroplasty ($n = 39$).

Factors	Elevation in differential temperature		
	Mild ($n = 8$)	Moderate ($n = 22$)	Severe ($n = 9$)
Differential skin temperature, °C	0.50 ± 0.22	2.04 ± 0.67	3.30 ± 0.40
HSS Score			
Preoperative visit	53.25 ± 3.20	55.73 ± 1.83	57.44 ± 4.33
Last follow-up visit	90.50 ± 3.96	88.59 ± 2.26	89.44 ± 1.42
Difference between visits	37.25 ± 4.77*	32.86 ± 1.83	32.00 ± 1.42

Values are shown as mean ± SD.

The differential temperature (i.e. operated knee minus the contralateral knee) was categorized as a mild (< 1.0°C), moderate (1.0–3.0°C) or severe elevation (> 3.0°C).

* $P < 0.05$ compared with moderate or severe elevation groups.

preoperative values, which is in accord with these present findings.²⁵ However, the present study found that the differential temperature was significantly higher at 12 months after surgery compared with the preoperative value, which suggests a longer follow-up is required to monitor the exact recovery time needed to exclude the possibility of joint infection. The present study also found that the knee skin temperature and differential temperature were highest in the inferiomedial area of knee compared with other areas.

Many factors could account for increases in the operated knee skin temperature including surgical trauma and/or an irritation response from the implant insertion.²⁶ The results from the current multivariate regression analysis showed that HCT and days after surgery were inversely correlated and BMI and ASA scores at baseline were positively correlated with the postoperative differential knee temperature. The present study also observed a strong inverse correlation between the grade of differential temperature elevation and HSS score improvement, which may account for patients' dissatisfaction with the procedure.^{3–6}

To the best of our knowledge, this present study is one of the first to explore the roles of

HGB, WBC, HCT, K–L classification and ASA score in knee skin temperature changes following TKA. In addition, we believe it is the first to investigate the relationship between the degree of differential temperature elevation and clinical outcome improvement. However, this present study had a number of limitations that should be considered. First, a relatively small number of patients was involved in the study and so further studies with larger numbers of patients are required to strengthen these findings. Secondly, there were many more females than males and so the results may not be reliable for both sexes. Thirdly, the present study did not evaluate the influence of surgical procedures, such as implant sizes or tourniquet application time, on knee skin temperature. Finally, none of the patients had evidence of a joint infection and so we could not investigate if increased local skin temperatures were indeed associated with periprosthetic joint infections.

In conclusion, differential knee skin temperature elevation 12 months post-TKA may be a normal surgical response. This present study provides data on the superficial skin temperature changes and the relationship with serum indices and outcome following TKA. Further investigations are required to confirm if increased local skin

temperatures are indeed associated with periprosthetic joint infections.

Declaration of conflicting interests

The authors declare that there are no conflicts of interest.

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