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Hyperthermia associated with spinal radiculopathy as determined by digital infrared thermographic imaging

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Abstract

In general, in digital infrared thermographic imaging (DITI) of patients with unilateral spinal radicular pain, the thermal pattern of the extremities of the side of lesion shows hypothermia compared to the opposite, intact side. However, sometimes, DITI shows hyperthermia on the side of the lesion, and this variation can cause confusion. We compared the data of both hypothermia and hyperthermia patients to clarify the factors determining different thermal characteristics in spinal radiculopathy.

We retrospectively collected data from patients who underwent DITI at a single center. The final cohort (n = 224) was allocated into 2 groups, a hypothermia group (n = 180) or a hyperthermia group (n = 44). We compared the various factors, including demographic factors and symptom-related factors, that might affect the results of DITI.

Except the presence of trauma history (13.9% vs 31.8%, odds ratio 2.893, $P = .008$), no significant intergroup difference was found in baseline demographic factors, including age, gender, diabetes mellitus, spinal level of pathology, and intervention history. Among symptom-related factors, in the hyperthermia group, the symptom duration was shorter (10.64 weeks [95% confidence interval (CI) 8.36–13.04] vs 2.10 weeks [95% CI 1.05-3.53], $P < .001$) and Visual Analogue Scale (VAS) of radicular pain was higher (4.23 ± 1.29 vs 5.18 ± 1.40, $P < .001$) than in the hypothermia group. Also, in the regression analysis, significant factors for hyperthermia include the presence of trauma history, shorter symptom duration (cut-off value 2.50 weeks or less) and higher VAS of radicular pain (cut-off value 4.50 or more).

In patients with trauma history, acute phase, and severe radicular pain, hyperthermia in DITI is not unusual and careful interpretation of the DITI results is necessary for proper diagnosis and treatment decisions in spinal radiculopathy.

Abbreviations: CI = confidence interval, DITI = digital infrared thermographic imaging, DM = diabetes mellitus, MRI = magnetic resonance imaging, OR = odds ratio, ROC = receiver operating characteristic, VAS = visual analogue scale.

Keywords: digital infrared thermographic imaging, hyperthermia, hypothermia, radiculopathy, spine

1. Introduction

Compression and inflammation of the cervical or lumbar nerve root by disc herniation or spinal stenosis causes radicular pain of the upper or lower extremities, which is a typical symptom of spinal radiculopathy. This unilateral spinal nerve root entrapment causes hypothermia of the affected area on the side on the lesion compared to the normal, contralateral side because of autonomic nervous system dysfunction.[1–3] In other words, unilateral spinal radiculopathy by pathology around the cervical or lumbar nerve root, such as disc herniation and stenosis, causes not only radicular pain due to nerve irritation, but also decrease of skin temperature due to sympathetic excitation and active vasoconstriction of the extremities on the side of the lesion.[4,5] Based on this concept, digital infrared thermographic imaging (DITI) has been used to objectively visualize the change in skin temperature in patients with spinal radiculopathy.[6,7]

DITI is helpful, as a complementary diagnostic tool, for confirming an accurate diagnosis and determining a treatment plan by identifying the dermatome and affected nerve root.[8,9] A significant temperature difference is defined as a temperature difference of more than 0.1 to 0.3°C between both sides depending on the part; for example, more than 0.1°C in proximal part and more than 0.3°C in distal part of extremities.[4,5,9]

In general, as mentioned above, the thermal pattern of the extremities on the side of the lesion shows hypothermia compared to the opposite, intact side using DITI. However, sometimes, DITI shows hyperthermia on the side of the lesion compared to the opposite intact, side.[5] We believed that this paradoxical phenomenon could be caused by several situations including the presence of combined diabetic or peripheral neuropathy, bilateral spinal radiculopathy, a previous spinal operation or intervention history, or examination errors.[10,11] Nevertheless, even after excluding these reasonable situations, occasionally, patients with unilateral spinal radiculopathy by a

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single nerve root entrapment exhibit hyperthermia in the affected dermatome, which can lead to confusion or misdiagnosis.

In this study, to prevent confusion or misdiagnosis of DITI results in patients with unilateral spinal radiculopathy, we sought to identify factors that affect hyperthermia.

2. Material and methods

2.1. Patient selection

A retrospective study was conducted using data collected at a single center from January 2014 to December 2016. Among the 770 patients who underwent DITI exams, 224 patients with single level unilateral spinal radiculopathy were selected as a final cohort after filtering the patients with the following exclusion criteria:

(1) other diagnoses such as peripheral nerve disease, complex regional pain syndrome, herpes neuralgia, bone or joint disease of the limbs, etc.;
(2) obscure magnetic resonance imaging (MRI) findings or DITI results to determine spinal radicular pain;
(3) previous spinal surgery;
(4) a comorbid opposite-side lesion or multi-segmental lesion on MRI; and
(5) incomplete medical records.

Among this final cohort, 180 patients (80.4%) showed a low affected dermatome temperature (hypothermia), and 44 patients (19.6%) showed a high affected dermatome temperature (hyperthermia) by DITI. According to this DITI result, patients were allocated to hypothermia or hyperthermia groups, respectively (Fig. 1).

This study was approved by the institutional review board of our hospital at June 26, 2018 (GAIRB 2018-213).

2.2. Data collection

We collected data for various factors that may affect DITI results. For baseline demographic characteristics, age, gender, diabetes mellitus (DM) history, spinal level of pathology (cervical or lumbar), recent trauma history that worsens symptom, and previous intervention history were collected. Previous intervention history is defined as a history of simple procedure such as epidural block, nerve root block, or percutaneous neuroplasty to the spinal lesion associated with the patient's symptoms at the time of DITI exam. We also collected symptom-related factors such as symptom duration, Visual Analogue Scale (VAS) of radicular pain, and presence of muscle weakness.

We compared the hyperthermia group to the hypothermia group for all above variables.

2.3. Equipment and examination

DITI was performed using the Iris-XP Digital infrared imaging system (Medicore, Seoul, South Korea). Patients scheduled for DITI were told about general precautions such as to avoid exposure to cold or hot environments, not to smoke, not to consume caffeine, etc. for one hour before imaging. After undressing, patients remained in a room maintained at 20.0 to 23.0°C for about 20 minutes to adapt prior to imaging. Quantitative analysis of DITI images, including temperature differences between both sides of limbs, was performed by a certificated doctor unaware of patient information.

According to previous references, if the difference is greater than 0.1 to 0.3°C between sides, it is defined as a meaningful result, depending on the surface area.[4,5,9]

2.4. Statistical analysis

The analysis was conducted using SPSS version 19.0 (SPSS Inc, Chicago, IL). We used Pearson Chi-square test, independent t-

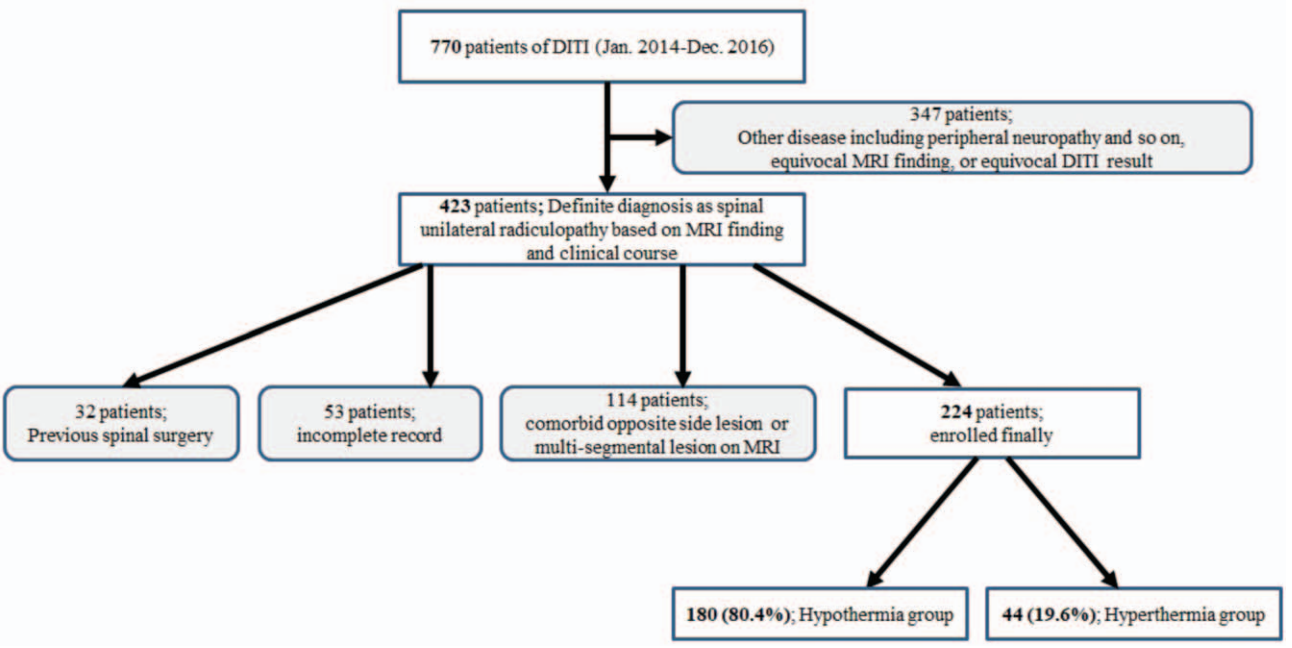

Figure 1. Screening of patients for final cohort selection. DITI = Digital infrared thermographic imaging, DM = diabetes mellitus, MRI = magnetic resonance imaging.

test, and non-parametric Mann-Whitney *U* test for univariate comparison according to characteristics of the factors. Also, we performed a dichotomous logistic regression analysis of variables that were assumed to have a $P \leq .2$ in univariate analysis.

Statistical significance was accepted for $P < .05$.

3. Results

3.1. Overall data

Mean age of all patients (n = 224) was 54.8 ± 14.2 years old, 120 patients (53.6%) were male, 25 patients (11.2%) had a DM, 39 patients (17.4%) had a symptom-related trauma history, and 104 patients (46.4%) had a previous history of spinal intervention. Among all patients, 65 patients (29.0%) had a cervical spine lesion and 159 patients (71.0%) had a lumbar spine lesion. Median duration of symptoms before undergoing DITI was 8.96 weeks (95% confidence interval (CI) 7.06–10.87), mean VAS of radicular pain was 4.41 ± 1.40, and 31 patients (13.4%) presented with muscle weakness.

3.2. Univariate analysis

Among the baseline demographic factors, only the presence of trauma history showed significant difference between the 2 groups (25 patients [13.9%[in the hypothermia group vs 14 patients [31.8%] in the hyperthermia group, $P = .008$, Pearson Chi-square test). Other factors including age, gender, presence of DM, spinal level of pathology, and previous history of intervention were not different between the two groups (Table 1).

Among the symptom-related factors, the symptom duration (10.64 weeks [95% CI 8.36-13.04] in hypothermia group vs 2.10 weeks (95%CI 1.05–3.53) in hyperthermia group, $P < .001$, non-parametric Mann-Whitney *U* test) and VAS for radicular pain (4.23 ± 1.29 in hypothermia group vs 5.18 ± 1.40 in hyperthermia group, $P < .001$, independent *t* test) were significantly different between the 2 groups (Table 2).

3.3. Regression analysis

According to univariate analysis, presence of DM, presence of trauma history, symptom duration, VAS of radicular pain, and presence of muscle weakness were considered to be relevant variables ($P < .2$) and dichotomous logistic regression analysis was performed on the above variables.

As a result, trauma history (odds ratio (OR) 0.444, 95% CI 0.180–0.992, $P = .027$), symptom duration (OR 0.839, 95% CI 0.744–0.947, $P = .005$) and VAS of radicular pain (OR 1.758, 95% CI 1.309–.361, $P < .001$) were significant factor influencing hyperthermia in DITI. In other words, in the hyperthermia group, trauma history was more common, symptom duration was shorter, and VAS of radicular pain was higher than in the hypothermia group (Table 3).

3.4. Cut-off value for hyperthermia

According to Receiver Operating Characteristic (ROC) curve for the hyperthermia group, symptom duration and VAS of radicular pain were proven as significant independent variables (AUC = 0.796, 95% CI 0.724–0.868, $P < .001$, and AUC = 0.699, 95% 0.614–0.784, $P < .001$, respectively) (Figs. 2 and 3).

The cut-off value of the symptom duration was 2.50 weeks (sensitivity 0.841, specificity 0.628) and the cut-off value of the VAS of radicular pain was 4.50 (sensitivity 0.636, specificity 0.717). In other words, if the symptom duration is shorter than 2.50 weeks, or the VAS of radicular pain is higher than 4.50, it is more likely to appear hyperthermia in DITI.

4. Discussion

Several previous studies have reported that 7.0% to 14.3% of patients with spine radiculopathy showed hyperthermia.[2,3,12] In the present study, 44 of the 224 (19.6%) showed hyperthermia, which similar with previous reports.

Some authors have proposed hypothesis for a hyperthermia associated with spinal radiculopathy. Uematsu[3] reported that temperature of extremities may show different aspects depending on the extent of injury to the peripheral nerve. Namely, complete peripheral nerve injury causes loss of autonomic nervous system function resulting in hyperthermia due to blood vessel dilation, whereas incomplete peripheral nerve injury causes autonomic nervous system activation resulting in hypothermia due to norepinephrine synthesis and blood vessel constriction.[13] However, in our study, most patients showed nerve root entrapment rather than complete nerve root disruption in MRI findings, and patients' symptoms were not complete paralysis or complete hypoesthesia of the affected dermatome. Also, the presence of muscle weakness was not statistically correlated with hyperthermia in this study. These observations and conjectures are not in accord with previous proposals.

Interestingly, in the hyperthermia group, we found that more patients had trauma history than the hypothermia group. From this finding, we estimate one hypothesis to explain this phenomenon.

Acute direct nerve injury or acute nerve entrapment due to trauma can cause severe nerve injury close to the complete nerve injury. This severe nerve injury close to the complete nerve

Table 1

Demographic characteristics including age, gender, prevalence of diabetes mellitus (DM), level of pathology, trauma history, and previous history of intervention in the 2 groups (independent *t* test or Pearson Chi-square test).

		Hypothermia group (n = 180)	Hyperthermia group (n = 44)	OR or difference	95% CI	*P* value
Age		55.34 ± 14.11	52.48 ± 14.29	2.87 ± 2.38	−1.82–7.55	.700
Male ratio		93 (51.7%)	27 (56.8%)	0.673	0.343–1.320	.312
DM		23 (12.7%)	2 (4.5%)	0.325	0.074–1.434	.180
Level	Cervical	53 (29.4%)	12 (27.3%)	0.970	0.791–1.190	.854
	Lumbar	127 (70.6%)	32 (72.7%)	1.080	0.634–1.839	
Trauma		25 (13.9%)	14 (31.8%)	2.893	1.350–6.200	.008
Intervention		83 (46.1%)	21 (47.7%)	1.067	0.551–2.065	.868

* CI = confidence interval, DM = diabetes mellitus, OR = Odds ratio.

Table 2

Symptom-related characteristics including symptom duration, visual analogue scale (VAS) of radicular pain, and prevalence of motor weakness in the two groups (non-parametric Mann–Whitney *U* test, independent *t* test, or Pearson Chi-square test).

	Hypothermia group (n = 180)	Hyperthermia group (n = 44)	OR or difference	95% CI	*P* value
Symptom duration (weeks)	10.64 (95% CI 8.36–13.04)	2.10 (95% CI 1.05–3.53)	8.54	3.87–13.20	<.001
VAS	4.23 ± 1.29	5.18 ± 1.40	0.95 ± 0.22	0.52–1.39	<.001
Weakness	21 (11.6%)	10 (22.7%)	2.227	0.962–5.154	.085

*CI = confidence interval, OR = Odds ratio, VAS = visual analogue scale.

Table 3

Dichotomous logistic regression analysis of various variables between the two groups.

	Hypothermia group (n = 180)	Hyperthermia group (n = 44)	OR	95% CI	*P* value
DM	23 (12.7%)	2 (4.5%)	5.211	0.942–28.820	.059
Trauma history	25 (13.9%)	14 (31.8%)	0.444	0.180–0.992	.027
Symptom duration	10.64 (95% CI 8.36–13.04)	2.10 (95% CI 1.05–3.53)	0.839	0.744–0.947	.005
VAS	4.23 ± 1.29	5.18 ± 1.40	1.758	1.309–2.361	<.001
Muscle weakness	21 (11.6%)	10 (22.7%)	0.458	0.157–1.333	.152

*CI = confidence interval, DM = diabetes mellitus, OR = Odds ratio, VAS = visual analogue scale.

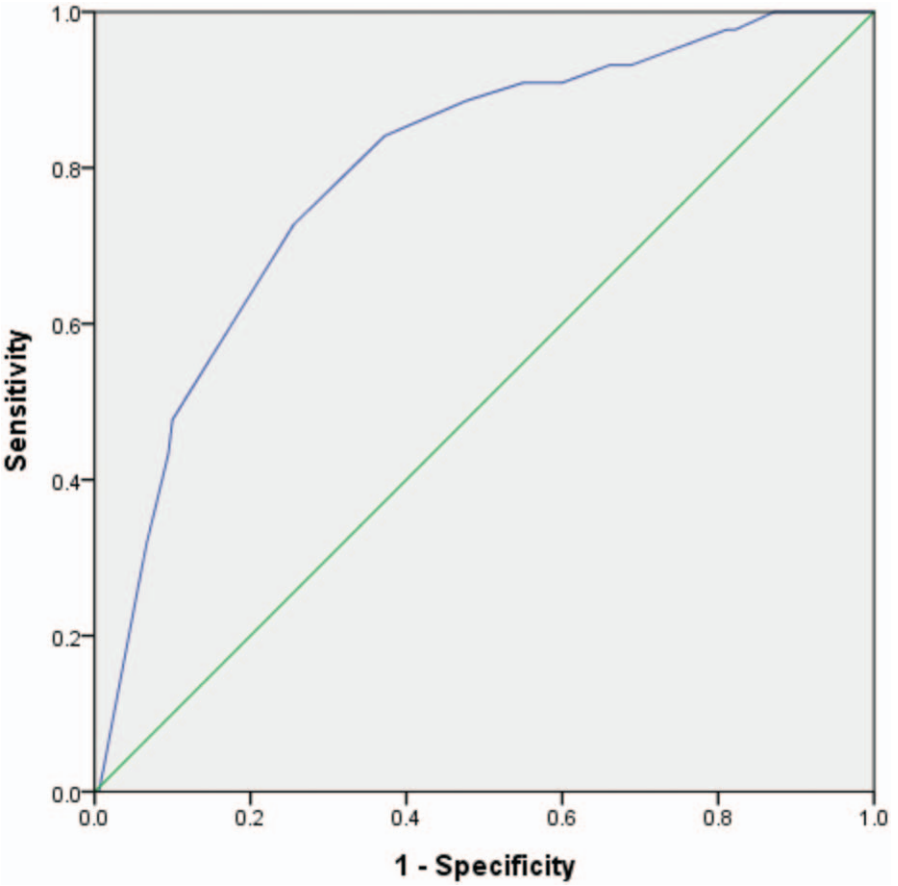

Figure 2. ROC (Receiver Operating Characteristic) curve of symptom duration for the hyperthermia group (AUC = 0.796 (95% CI 0.724–0.868), cut-off value = 2.50 weeks or less (sensitivity 0.841, specificity 0.628), $P < .001$).

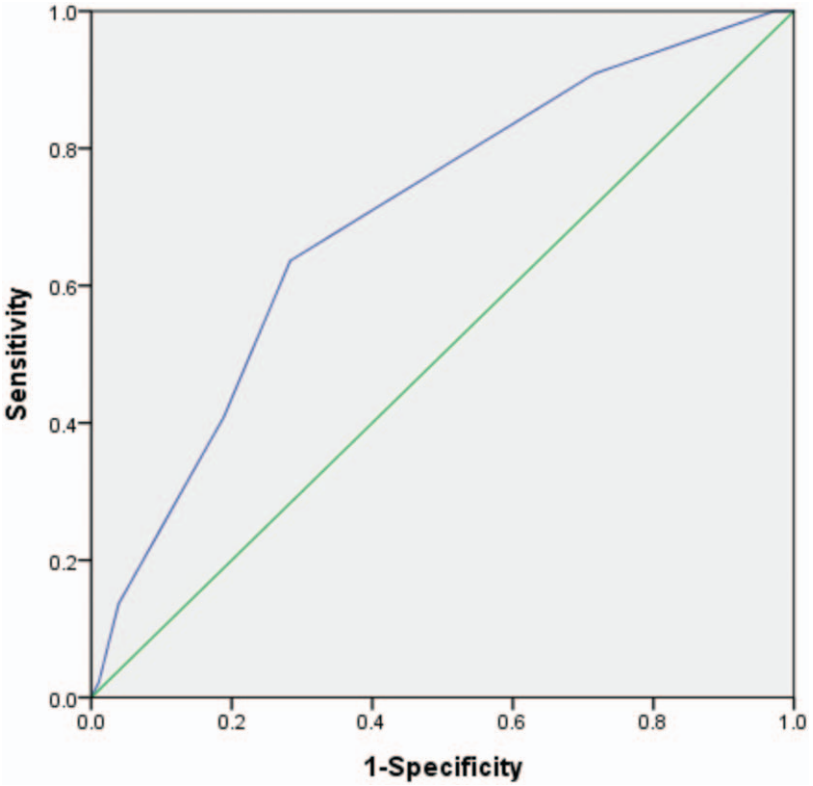

Figure 3. ROC (Receiver Operating Characteristic) curve of VAS of radicular pain for the hyperthermia group (AUC = 0.699 (95% 0.614–0.784), cut-off value = 4.50 or more (sensitivity 0.636, specificity 0.717), $P < .001$).

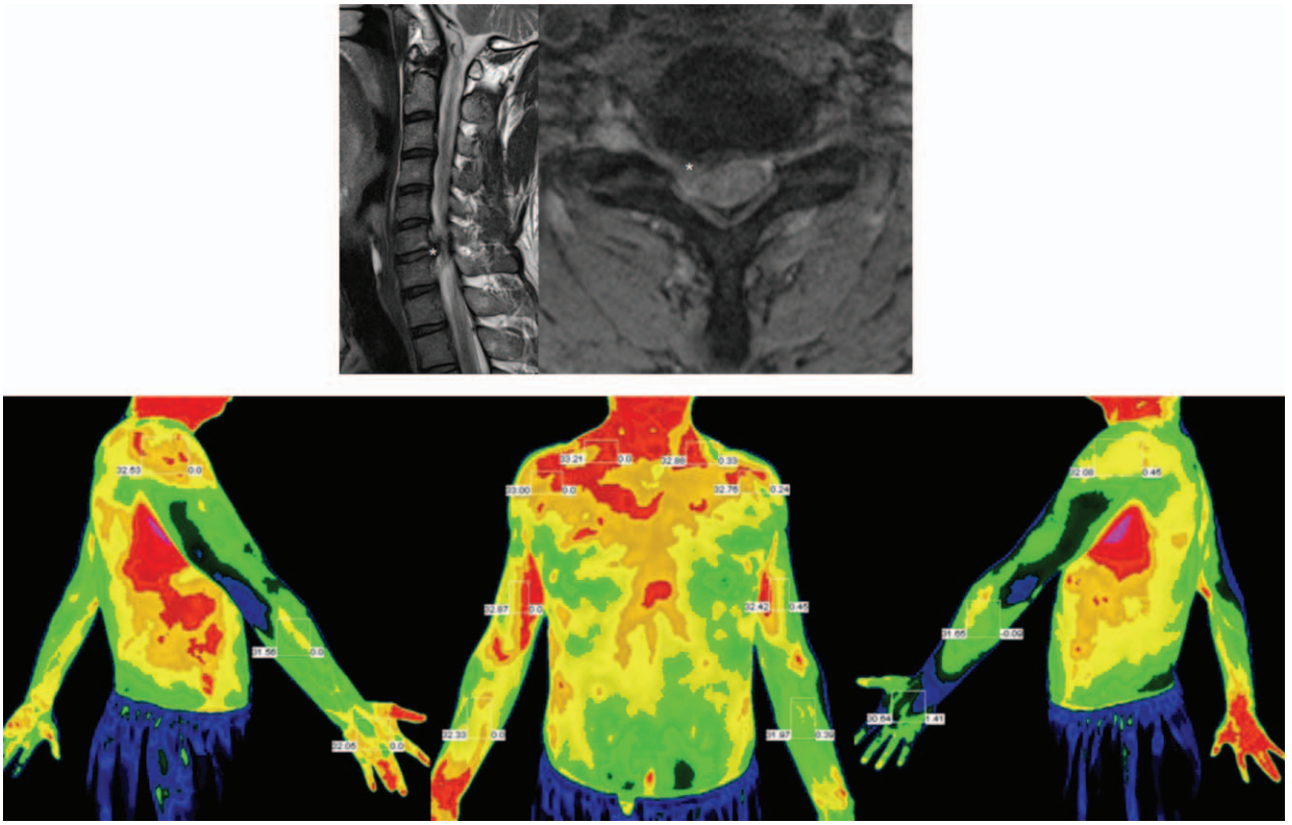

Figure 4. Illustration of case 1. A. Cervical magnetic resonance imaging showed a larger ruptured disc (asterisk) at the right side of C6-7 level after trauma of falling down. B. Digital infrared thermographic imaging showed higher temperature in the dermatome of right C7.

injury may lead to loss of autonomic nervous function, not activation of autonomic nervous system. Therefore, this loss of autonomic nervous function showed hyperthermia due to vasodilation rather than hypothermia due to vasoconstriction in lesion side.

As case illustration 1, typical hyperthermia of lesion side was observed in patient with large amount of cervical disc herniation after falling accident (Fig. 4).

Also, the hyperthermia group had shorter symptom duration (cut-off value $\leq$2.50 weeks) and higher VAS for radicular pain (cut-off value $\geq$4.50) than the hypothermia group. We estimate two hypotheses to explain this phenomenon.

First, we believe that severe radicular pain may cause not only shorter pre-hospital period due to intolerable pain but also hyperthermia of lesion side due to severe nerve root compression or injury close to complete nerve injury. In previous studies, it was mentioned that disc herniation compressing neve root severely or disc herniation compressing dorsal root ganglion directly is associated with more severe radicular pain.[14,15] In other words, more severe radicular pain is related with severe nerve root compression or injury close to complete nerve injury. Also, this severe pain would have prompted the patient to visit the hospital quickly.

Second, we guess that the characteristics of autonomic dysfunction in acute phase or chronic phase of nerve compression or injury are different each other. For example, in acute phase, the degree of pain is severe and the autonomic dysfunction is close to the shut-down of vasoconstriction function, whereas, in chronic phase, the degree of pain is tolerable and the autonomic dysfunction is close to irritation or hyper-activation of vasoconstriction function.

Case illustration 2 showed hyperthermia of lesion side in patient with acute severe leg pain and complete nerve root compression (Fig. 5).

In the present study, we did not estimate the degree of nerve root compression or injury quantitatively in MRI, and thus, the study did not reveal much about the relationship between the autonomic nervous system and degree of nerve root compression or injury. However, the present study showed that in patient with trauma history, short symptom duration, or severe radicular pain, DITI can reveal hyperthermia in lesion side, and this phenomenon may indicate severe nerve root compression or injury. Accordingly, in the patient with hyperthermia on the symptom side in DITI, careful interpretation and clinical correlation is needed to achieve a correct diagnosis and to ensure adequate treatment.

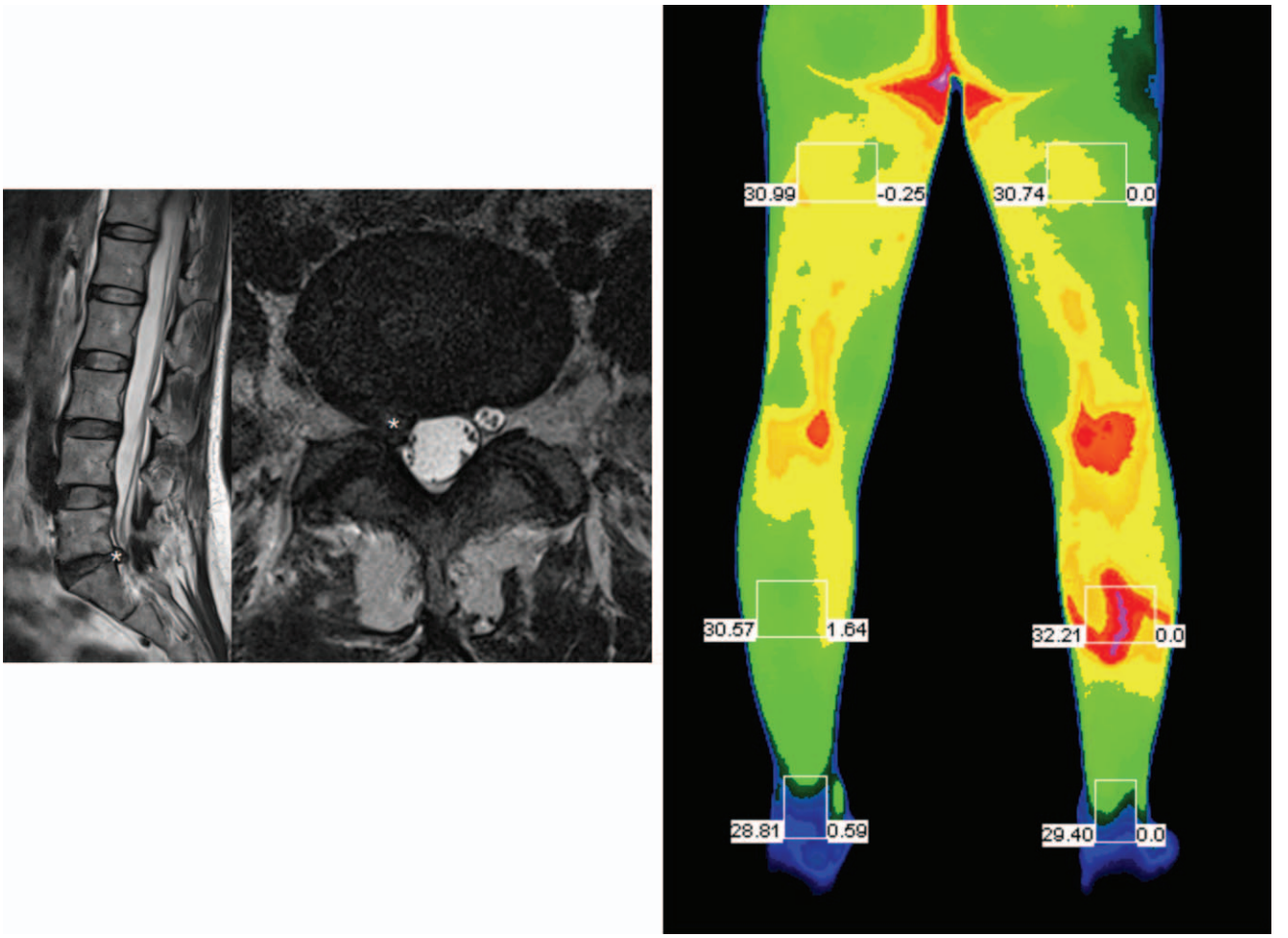

Figure 5. Illustration of case 2. A. In a patient with severe acute right leg pain (onset of symptom; 1 week ago, and Visual Analogue Scale of right leg; 8), lumbar magnetic resonance imaging showed a complete compression of right S1 root due to ruptured disc (asterisk) at the right side of L5-S1 level. B. Digital infrared thermographic imaging showed higher temperature in the dermatome of the right S1.

This study has some limitations. First, we did not control the patient's environment absolutely same when we performed DITI exam. In other words, all physiological or psychological factors such as circadian rhythm, emotional stress, depression, and so on which can affect autonomic dysfunction were not controlled. However, this limitation was mitigated by the fact that we assessed only the temperature difference between both limbs, not the absolute skin temperature value. Second, due to its retrospective nature, it was impossible to control for all variations. Nevertheless, we tried to minimize errors by precluding variables associated with a high body temperature, for example patients with other diagnosis, history of previous surgical history, and comorbid opposite side lesion in MRI. Third, the number of patients of final cohort was not large enough, and the study was conducted at a single center. However, to the best of our knowledge, this study is the first report to investigate the influencing factor for hyperthermia in lesion side in patients with spinal radiculopathy.

5. Conclusion

In patients with cervical or lumbar spine radiculopathy, a high body temperature on the pathologic side determined by DITI is not uncommon. In particular, presence of trauma history, short symptom duration, and severe radicular pain is associated with hyperthermia. We conclude that in patients with above predisposing factors, careful interpretation of the DITI result is necessary for correct diagnosis and proper treatment decision.

Author contributions

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Visualization: Seong Son.
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