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Original Article

Thermatomal Changes in Cervical Disc Herniations

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Abstract

Subjective symptoms of a cool or warm sensation in the arm could be shown objectively by using of thermography with the detection of thermal change in the case of radiculopathy, including cervical disc herniation (CDH). However, the precise location of each thermal change at CDH has not been established in humans. This study used digital infrared thermographic imaging (DITI) for 50 controls and 115 CDH patients, analyzed the data statistically with t-test, and defined the areas of thermatomal change in CDH $C_{3/4}$, $C_{4/5}$, $C_{5/6}$, $C_{6/7}$ and $C_{7/T1}$. The temperature of the upper trunk and upper extremities of the control group ranged from 29.8°C to 32.8°C. The minimal abnormal thermal difference in the right and left upper extremities ranged from 0.1°C to 0.3°C in 99% confidence interval. If ΔT was more than 0.1°C, the anterior middle shoulder sector was considered abnormal ($p<0.01$). If ΔT was more than 0.3°C, the medial upper aspect of the forearm and dorsal aspect of the arm, some areas of the palm and anterior part of the fourth finger, and their opposite side sectors and all dorsal aspects of fingers were considered abnormal ($p<0.01$). Other areas except those mentioned above were considered abnormal if ΔT was more than 0.2°C ($p<0.01$). In $p<0.05$, thermal change in CDH $C_{3/4}$ included the posterior upper back and shoulder and the anterior shoulder. Thermal change in CDH $C_{4/5}$ included the middle and lateral aspect of the triceps muscle, proximal radial region, the posterior medial aspect of the forearm and distal lateral forearm. Thermal change in CDH $C_{5/6}$ included the anterior aspects of the thenar, thumb and second finger and the anterior aspects of the radial region and posterior aspects of the pararadial region. Thermal change in CDH $C_{6/7}$ included the posterior aspect of the ulnar and palmar region and the anterior aspects of the ulnar region and some fingers. Thermal change in CDH $C_{7/T1}$ included the scapula and posterior medial aspect of the arm and the anterior medial aspect of the arm. The areas of thermal change in each CDH included wider sensory dermatome and sympathetic dermatome. There was a statistically significant change of temperature in the areas of thermal change in all CDH patients. In conclusion, the areas of thermal change in CDH can be helpful in diagnosing the level of disc protrusion and in detecting the symptomatic level in multiple CDH patients.

Key Words: Cervical disc herniation, thermography, thermatome, thermal difference

INTRODUCTION

The skin has many blood vessels and nerves and it plays a significant role in temperature control for our bodies. Thermoregulations within a few millimeters from the skin surface are controlled by the autonomic nervous system. Localized and asymmetric temperature changes of the skin surface have been noted since the Hippocratic era. Hippocrates found that the area of lesion was the faster drying area after spreading wet mud over the surface of the body, where the focus of fever was localized. This is the oldest known record of thermographic examination.[1] Infrared thermography was first used clinically by Leo Massopurt in 1948, and the first documentary record was done by taking the thermography of a breast cancer patient.[2]

In 1800, William Herschel classified the entire range of light and named the invisible high-energy ray as infrared. The heat radiating from a body consists of infrared rays ranging in wavelength from 3 mm to 10 mm. In recent years, optical and computer technologies have improved and digital infrared thermographic imaging (DITI) has been developed. It can measure the temperature of any area of the body surface exactly and objectively without any discomfort or hazard.

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Neck pain, radiating arm pain and the sensation of cold or hot in the involved arm due to compression of the nerve root by cervical disc herniation (CDH) are subjective symptoms. If the patients complain of these symptoms, a doctor can't prove it objectively by ordinary means. The area of radiating arm pain is distributed within the involved dermatome. DITI shows the painful arm in CDH as a hypothermic or hyperthermic change with radiating pattern. Subjective symptoms of thermal change in the arm could be shown objectively by using contact-type liquid crystal thermography and detection of the thermal change of the arm in the case of radiculopathy, including CDH. This thermography was reported to be useful for the diagnosis of the CDH.[3]

This study recorded the temperature distribution of the control cases and thermal change areas in each CDH. The temperature distribution of the arm and upper trunk in normal controls was analyzed with the DITI of the control group. The abnormal thermal differences of the right and left arms were made with normal thermal distributions. And the thermal change areas of each CDH were made by comparing the normal DITIs and DITIs of radiologically-proven CDH patients.

MATERIALS AND METHODS

Equipment and procedure

Thermography was taken with a Digital Infrared Thermographic Imaging device (Dorex Inc, West Collins, CA, U.S.A.) at 23°C shielded from outdoor light and heat. The controls and patients were requested to undress and to remain in the laboratory for approximately 15 minutes and to stand to allow the skin surface temperature to adjust to room temperature. DITI of the trunk and arm was taken at a distance of 1.5 m. DITI of both hands was taken at a distance of 1 m.

For the temperature measurements in the DITIs of the control group and patient group, we divided the anterior aspect of the arm and trunk into 28 sectors on each side, and also divided the posterior aspect of the arm and trunk into 27 sectors on each side. Thus, the trunk and arms of each subject had 110 sectors, and we measured and analyzed the mean temperature of each sector (Fig. 1).

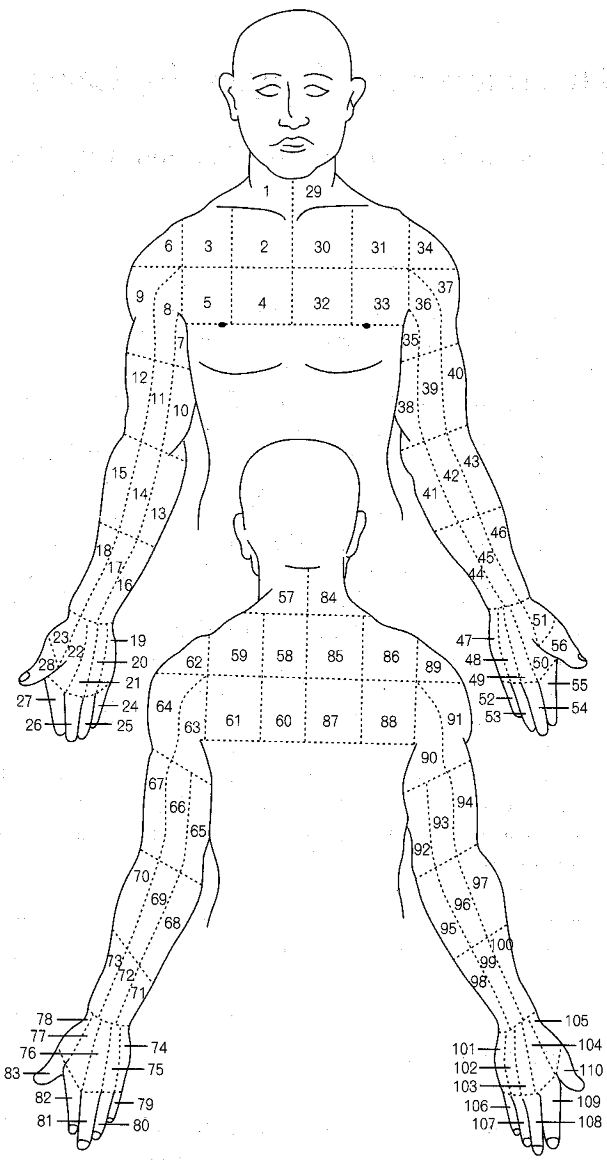

Fig. 1. Measurement sectors of skin temperature. The anterior aspect of the arms and trunk has 28 sectors in each side, while the posterior aspects have 27 sectors in each side. Skin temperature was measured in each sector.

Measurement of skin temperature in the control group

The control group consisted of normal adults who reported not having any neck pain and disease, or any arm or trunk pain or disease. All 50 cases (24 males, 26 females, mean age 32.5 years) thermograms of the arms and trunk were taken (Table 1).

If a thermal difference in the left and right symmetric sectors did not exist, 110 sectors of 50 cases could be simplified into 55 sectors in the arm and trunk on one side of 100 cases. Each normal distribution of 55 sectors was made for 100 cases and the data was compared to the normal temperature of each sector. The normal distribution of thermal differences of each of 55 sectors in 50 cases was also determined.

Measurement of skin temperature in the patient group

The patient group was limited to the patients who had visited and been diagnosed one side single level CDH without any other disease in the Spine Center of Yongdong Severance Hospital from January, 1993 to March, 1997. Measurements of the skin temperature were done in the preoperative DITIs of the CDH patients of $C_{3/4}$, $C_{4/5}$, $C_{5/6}$, $C_{6/7}$ and $C_{7/T1}$ who satisfied the above conditions. The distribution of the thermal differences between the healthy and painful arms was made by subtracting each sector temperature of the healthy side minus the corresponding sector on the opposite side. A total of 115 patients were measured (Table 1 and 2).

Table 1. Age and Sex Distributions of Control (n=50) and Patient Groups (n=115)

Age (Yrs.)	Control		Patients	
	Male	Female	Male	Female
10–19	0		0	0
20–29	12	14	2	2
30–39	5	9	8	10
40–49	5	1	20	15
50–59	2	0	23	14
60–69	0	1	10	16
70–79	0	0	3	2
Sub-total	24	26	66	49
Total	50		115	

Table 2. Patient Distribution According to the Level of CDH* (n=115)

Level of CDH*	No. of patients	%
C3/4	9	7.8
C4/5	11	9.6
C5/6	57	49.6
C6/7	30	26.1
C7/T1	8	6.9

*cervical disc herniation.

Statistical analysis

The temperature data for 110 sectors in the patient group were divided into 55 sectors on the healthy side and 55 sectors on the painful side. These were analyzed with a t-test comparing the thermal differences for the control group and with the radiculopathy group for each sector. Each area of thermatomal change was made under the $p<0.01$ and $p<0.05$ of statistically significant differences.

RESULTS

Thermal distribution of the control group

The control group of normal subjects showed shoulder, the medial and proximal sectors of the upper arm, axillary area and cubital fossa distributed relatively high temperature, and the dorsal aspect of the upper arm and fingers were of relatively low temperature (Fig. 2, Table 3).

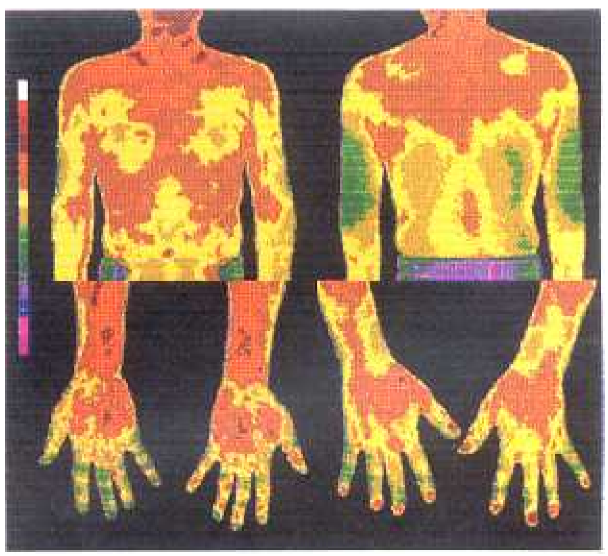

Fig. 2. Arm and trunk DITI of the control group. High temperature shows at the shoulder and axilla. Low temperature shows at the dorsal aspect of the upper arm and fingers.

Table 3. Thermal Distribution of Arm and Trunk in Control Group

No. of sector	Skin temperature*	DIS	No. of sector	Skin temperature	DIS	No. of sector	Skin temperature	DIS
1, 29	32.84±1.35	1.82	20, 48	31.69±1.59	2.54	66, 93	29.89±1.44	2.08
2, 30	32.58±1.35	1.81	21, 49	31.81±1.48	2.19	67, 94	30.10±1.54	2.36
3, 31	32.67±1.43	2.04	22, 50	31.48±1.64	2.70	68, 95	31.57±1.44	2.09
4, 32	32.19±1.49	2.22	23, 51	31.39±1.61	2.58	69, 96	31.65±1.42	2.01
5, 33	31.88±1.50	1.24	24, 52	30.18±2.36	5.55	70, 97	31.49±1.45	2.09
6, 34	32.56±1.38	1.90	25, 53	30.51±2.14	4.57	71, 98	31.49±1.45	2.09
7, 35	32.11±1.68	2.68	26, 54	30.49±1.92	3.67	72, 99	30.85±1.33	1.93
8, 36	31.76±1.58	2.49	27, 55	30.51±2.02	4.08	73, 100	30.85±1.33	1.77
9, 37	31.54±1.41	2.00	28, 56	30.79±2.22	4.91	74, 101	30.22±1.46	2.12
10, 38	31.26±1.47	2.17				75, 102	30.68±1.43	2.03
11, 39	31.48±1.51	2.28	57, 84	32.55±1.40	1.95	76, 103	30.78±1.33	1.77
12, 40	31.36±1.41	2.22	58, 85	32.24±1.41	1.99	77, 104	30.78±1.29	1.67
13, 41	31.56±1.43	1.78	59, 86	31.90±1.38	1.91	78, 105	30.93±1.32	1.75
14, 42	31.36±1.41	1.98	60, 87	32.19±1.46	2.14	79, 106	29.81±2.12	4.48
15, 43	31.13±1.36	1.84	61, 88	31.78±1.48	2.20	80, 107	30.16±1.97	3.88
16, 44	31.77±1.30	1.69	62, 89	31.88±1.47	2.16	81, 108	30.28±1.93	3.71
17, 45	31.86±1.27	1.61	63, 90	31.08±1.51	2.29	82, 109	30.31±1.95	3.81
18, 46	31.36±1.28	1.64	64, 91	31.16±1.48	2.21	83, 110	30.59±1.84	3.37
19, 47	31.39±2.04	4.15	65, 92	30.16±1.36	1.85			

DIS, dispersion.
*Mean±S.D. °C.

Thermal differences of right and left arm in the control group

The mean thermal difference of right and left arm (ΔT) in control group ranged between 0.01°C and 0.42°C (Table 4). DITI displayed the temperature down to one decimal place. Therefore the areas which could be confirmed abnormal under $p<0.01$ (99% confidence interval) if ΔT was more than 0.1°C included the anterior middle shoulder area. The areas which could be confirmed abnormal under $p<0.01$ if ΔT was more than 0.3°C were No. 13, 14 and 68 sectors of the forearm, No. 22, 23, and 25 of the hand and their opposite side sectors and all dorsal aspects of the fingers. Other areas, except those mentioned above could be confirmed abnormal under $p<0.01$ if ΔT was more than 0.2°C (Fig. 3).

Thermatomal change in CDH $C_{3/4}$

The area of thermatomal change in CDH $C_{3/4}$ was made by comparing the thermal differences of the control group with 9 cases of one side $C_{3/4}$ CDH under $p<0.01$ and $p<0.05$ (Table 5, Fig. 4 and 5). In $p<0.01$, significant thermal change showed the areas of the posterior upper back and shoulder. In $p<0.05$, significant thermal change showed the areas of $p<0.01$ and the areas of the anterior shoulder.

Thermatomal change in CDH $C_{4/5}$

The area of thermatomal change in CDH $C_{4/5}$ was made by comparing the thermal differences of the control group with 11 cases of one side $C_{4/5}$ CDH under $p<0.01$ and $p<0.05$ (Table 6, Fig. 6 and 7). In $p<0.01$, significant thermal change showed the areas of the middle and lateral aspect of triceps muscle and proximal radius. In $p<0.05$, significant thermal change showed the areas of $p<0.01$ and the areas of the posterior medial aspect of the forearm and distal lateral forearm.

Thermatomal change in CDH $C_{5/6}$

The area of thermatomal change in CDH $C_{5/6}$ was made by comparing the thermal differences of the control group with 57 cases of one side $C_{5/6}$ CDH under $p<0.01$ and $p<0.05$ (Table 7, Fig. 8 and 9).

Table 4. Mean Thermal Difference between Right and Left Arm and Minimal Abnormal Thermal Difference in Control Group (n=50)

No. of sectors	mean △T*	DIS	abNL △T†	No. of sectors	mean △T	DIS	abNL △T	No. of sectors	mean △T	DIS	abNL △T
1, 29	.06±.31	.10	.11	20, 48	.16±.49	.24	.18	66, 93	.06±.32	.10	.12
2, 30	.12±.30	.09	.11	21, 49	.06±.41	.17	.15	67, 94	.01±.45	.20	.16
3, 31	.16±.27	.08	.10	22, 50	.18±.59	.35	.22	68, 95	.08±.64	.42	.23
4, 32	.05±.39	.15	.14	23, 51	.12±.56	.32	.20	69, 96	.11±.47	.23	.17
5, 33	.01±.39	.15	.15	24, 52	.27±.49	.24	.18	70, 97	.13±.47	.22	.17
6, 34	.02±.35	.12	.13	25, 53	.28±.65	.42	.24	71, 98	.01±.38	.14	.14
7, 35	.14±.51	.26	.19	26, 54	.09±.43	.18	.17	72, 99	.10±.42	.18	.16
8, 36	.03±.35	.12	.13	27, 55	.16±.53	.28	.19	73, 100	.11±.43	.18	.17
9, 37	.12±.43	.18	.17	28, 56	.42±.81	.65	.20	74, 101	.07±.50	.25	.18
10, 38	.19±.51	.26	.19					75, 102	.08±.53	.28	.19
11, 39	.05±.39	.16	.14	57, 84	.08±.56	.32	.20	76, 103	.05±.43	.19	.17
12, 40	.15±.36	.13	.13	58, 85	.07±.44	.19	.16	77, 104	.02±.49	.24	.18
13, 41	.06±.56	.34	.22	59, 86	.16±.41	.17	.15	78, 105	.23±.49	.24	.18
14, 42	.05±.57	.33	.21	60, 87	.05±.40	.16	.15	79, 106	.11±.66	.44	.24
15, 43	.17±.35	.12	.13	61, 88	.25±.43	.19	.17	80, 107	.09±.67	.45	.24
16, 44	.04±.35	.13	.13	62, 89	.14±.40	.16	.15	81, 108	.09±.69	.48	.25
17, 45	.07±.40	.16	.15	63, 90	.08±.35	.12	.13	82, 109	.01±.65	.42	.24
18, 46	.07±.42	.18	.15	64, 91	.03±.47	.22	.17	83, 110	.01±.55	.30	.20
19, 47	.24±.40	.16	.15	65, 92	.05±.44	.20	.16				

DIS, dispersion.
* mean thermal difference, mean±S.D., °C.
† minimal abnormal thermal difference between right and left arm under $p<0.01$.

Table 5. Sectors of Significant Thermal Change in CDH $C_{3/4}$

	S6-S34		S9-S37		S58-S85		S59-S86		S62-S89		S64-S91	
	M	T	M	T	M	T	M	T	M	T	M	T
Control	.02	2.31*	.12	2.25*	−.07	2.91†	−.16	−3.24†	−.14	2.86†	.03	2.97†
$C_{3/4}$	−.35		−.27		.47		.60		−.42		−.48	

M, mean; T, t-value.
* t-test $p<0.05$.
† t-test $p<0.01$.

In $p<0.01$, significant thermal change showed the areas of anterior aspects of the thenar, thumb and second finger. In $p<0.05$, significant thermal change showed the areas of $p<0.01$ and the areas of anterior aspects of the radial region and posterior aspect of the pararadial region.

Thermatomal change in CDH $C_{6/7}$

The area of thermatomal change in CDH $C_{6/7}$ was made by comparing the thermal differences of the control group with 30 cases of one side $C_{6/7}$ CDH under $p<0.01$ and $p<0.05$ (Table 8, Fig. 10 and 11).

In $p<0.01$, significant thermal change showed the areas of the posterior aspect of the ulnar and palmar regions. In $p<0.05$, significant thermal change showed the areas of $p<0.01$ and the areas of anterior aspects of the ulnar region and some fingers.

Thermatomal change in CDH $C_{7/T1}$

The area of thermatomal change in CDH $C_{7/T1}$ was

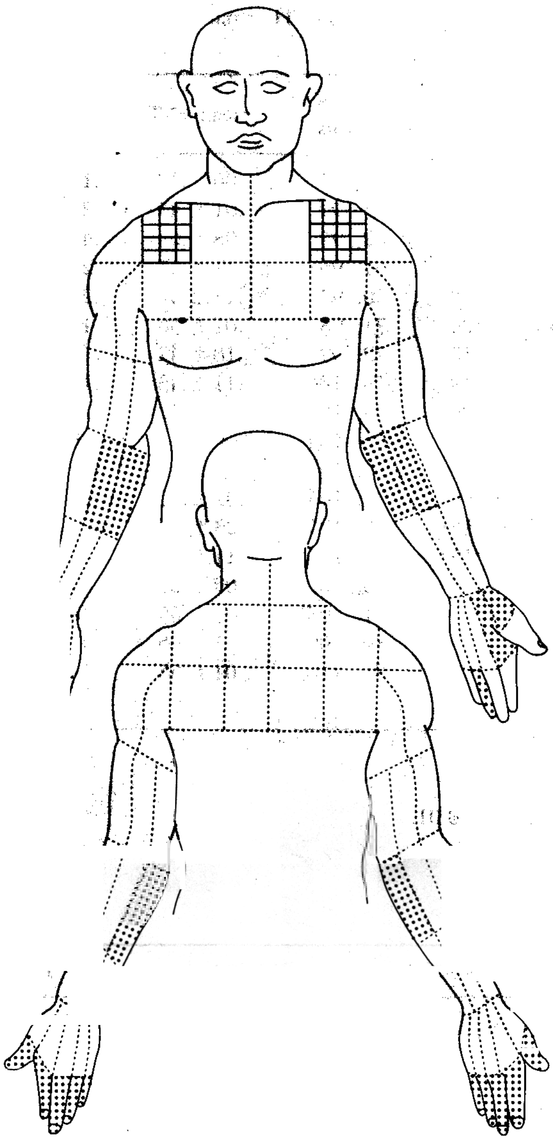

Fig. 3. Minimal abnormal thermal differences in 99% confidence interval ($p < 0.01$) between right and left arm in DITI shown with various marks, which represent one decimal place. Crossed sectors: These sectors can be recognized as abnormal if the thermal difference between opposite sectors is more than 0.1°C. No marking sectors: These sectors can be recognized as abnormal if the thermal difference between opposite sectors is more than 0.2°C. Dotted sectors: These sectors can be recognized as abnormal if the thermal difference between opposite sectors is more than 0.3°C.

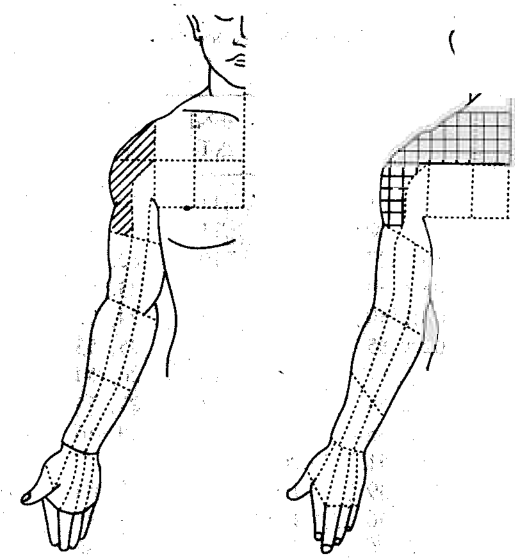

Fig. 4. The areas of significant thermal change in CDH $C_{3/4}$. The areas include the posterior upper back and shoulder. Crossed sector: $p < 0.01$. Crossed+slashed sector: $p < 0.05$.

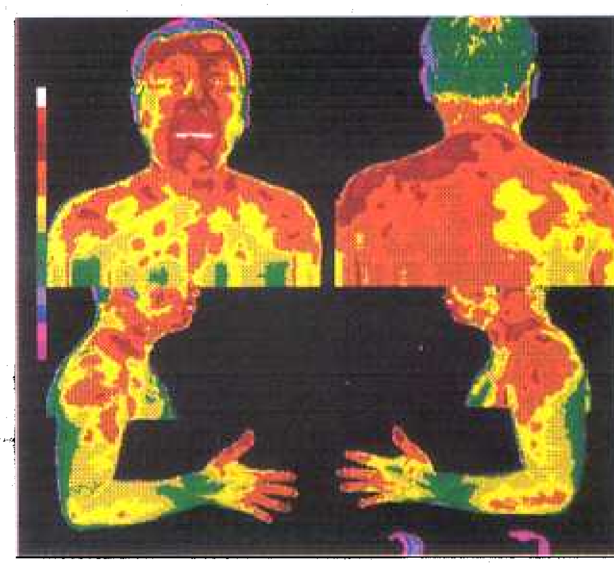

Fig. 5. Typical DITI of the $C_{3/4}$ CDH patient, which shows hypothermic change along the previously mentioned area as in Fig. 4.

made by comparing the thermal differences of the control group with 8 cases of one side $C_{7/T1}$ CDH under $p < 0.01$ and $p < 0.05$ (Table 9, Fig. 12 and 13).

In $p < 0.01$, significant thermal change showed the areas of the scapula and posterior medial aspect of the arm. In $p < 0.05$, significant thermal change showed the areas of $p < 0.01$ and the areas of the anterior medial aspect of the arm.

DISCUSSION

Temperature regulation of the skin is controlled by general functions and autonomic functions. Local

Table 6. Sectors of Significant Thermal Change in CDH $C_{4/5}$

	S12-S40		S15-S43		S63-S90	
	M	T	M	T	M	T
Control	.15	−2.28*	.17	2.84†	.08	2.38*
$C_{4/5}$	.52		−.47		.72	
	S64-S91		**S65-S92**		**S66-S93**	
	M	T	M	T	M	T
Control	.03	2.68†	.05	−2.11*	.06	2.72†
$C_{4/5}$	−.47		.31		−.40	

	S67-S94		S70-S97	
	M	T	M	T
Control	.01	2.24*	.13	−3.21†
$C_{4/5}$	−.37		1.62	

M, mean; T, t-value.
*t-test $p<0.05$.
†t-test $p<0.01$.

Table 7. Sectors of Significant Thermal Change in CDH $C_{5/6}$

	S15-S43		S17-S45		S18-S46	
	M	T	M	T	M	T
Control	.17	2.01*	−.07	2.42*	−.07	−2.17*
$C_{5/6}$	−.11		.30		.36	
	S23-S51		**S28-S56**		**S69-S96**	
	M	T	M	T	M	T
Control	−.12	−3.06*	.42	3.27†	.11	−2.29*
$C_{5/6}$	.39		−.05		.43	
	S73-S100		**S78-S105**		**S83-S110**	
	M	T	M	T	M	T
Control	.11	−2.41*	.23	2.26*	−.01	−2.84*
$C_{5/6}$	.38		−.25		.48	

M, mean; T, t-value.
*t-test $p<0.05$.
†t-test $p<0.01$.

muscular activity, antidromic stimulation from the sensory nerves and activation of the recurrent meningeal nerve from nerve root are thought to participate in the general functions of thermoregulation. Stimulation of a parasympathetic nerve, vascular constriction of a sympathetic nerve and partial regulation of a somatosympathetic reflex are thought to participate in the autonomic functions of thermoregulation.[4,5]

Antidromic stimulation of the sensory nerve was insisted upon by Bayliss in 1901 and supported by Sheehan in 1935.[6] Vascular dilatation in the extremities had been found after stimulation of the dorsal root, which suggested no relation to the sympathetic chain and ganglion. And neuronal change had not been found after dorsal root section. This study revealed a new pathway directed against the existing sensory pathway. This new pathway is thought to be that which has the neuron in the dorsal root ganglion, and the pathway of stimulus starts from the center to the peripheral part, contrary to the existing sensory pathway.

As well, the parasympathetic nervous system participates in the thermoregulation of the skin. Preganglionic fibers from the spinal gray matters pass through the dorsal root and dorsal root ganglion, changing postganglionic fiber, inducing the peripheral ganglion and changing the skin temperature.

Usually, the sympathetic nervous system provokes vascular constriction by secretion of adrenaline, but some cholinergic fiber of sympathetic nerves secretes acetylchoine and induces vascular dilatation and diaphoresis.[6,7]

Thermography is a well-known device for detection of the change of skin temperature and has been proposed as a diagnostic aid in patients with sciatica. Supporters of thermography state that normal patients should have normal thermograms of their extremities, while abnormal patients should have abnormal thermograms. In lumbar thermography, there is sensitive examination for detecting those patients who demonstrate lumbar spinal CT abnormalities and it should play an important role in the diagnostic screening of low back pain syndrome patients.[8] Some investigators have proposed that thermography is not useful as a diagnostic aid in sciatica.[9,10] But nowadays, many thermographers are investigating and they are insisting on the effectiveness of thermography with thermal change of the radiculopathy.[11,12]

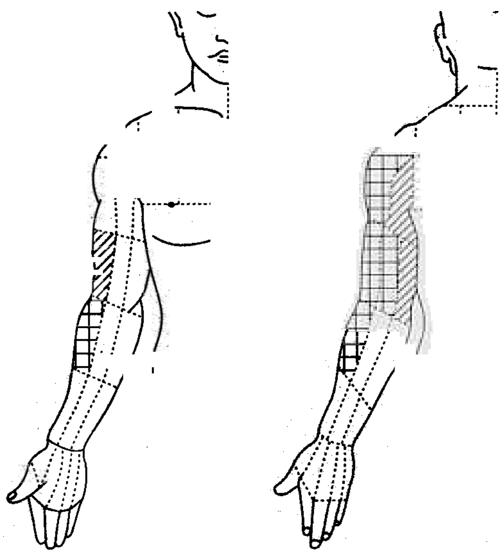

Fig. 6. The areas of significant thermal change in CDH $C_{4/5}$. The area is the triceps region.

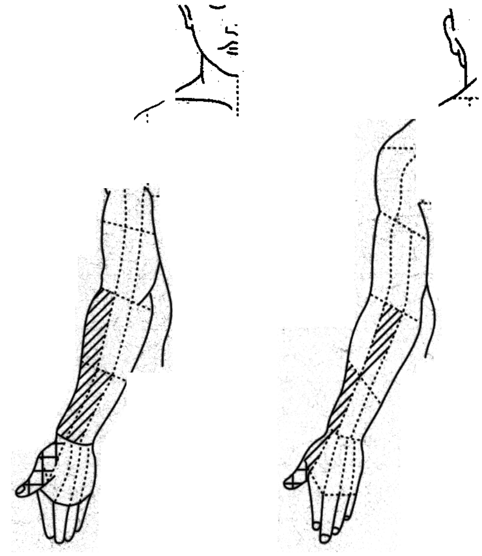

Fig. 8. The areas of significant thermal change in CDH $C_{5/6}$. The area is the thenar region.

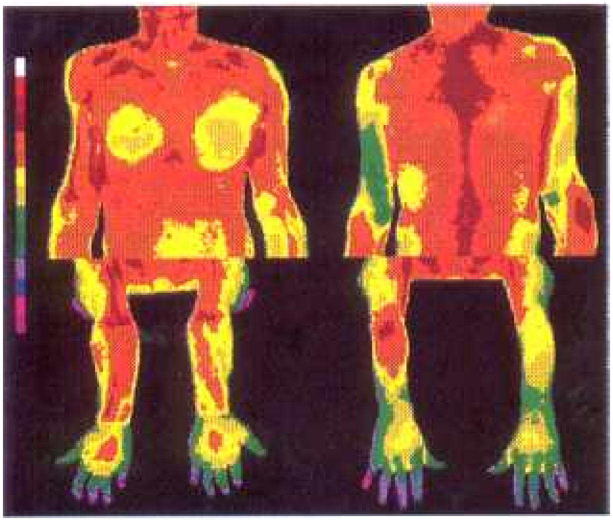

Fig. 7. Typical DITI of $C_{4/5}$ CDH patient, which shows hypothermic change along the previously mentioned area as in Fig. 6.

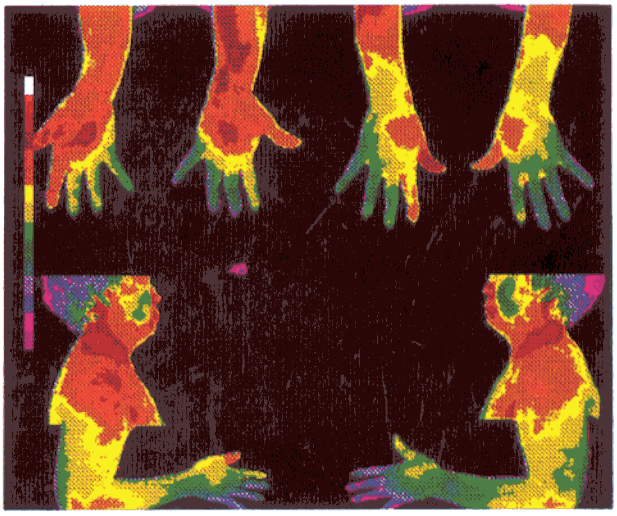

Fig. 9. Typical DITI of the $C_{5/6}$ CDH patient, which shows hypothermic change along the previously mentioned area as in Fig. 8.

Detection criteria for thermal asymmetry are important in the interpretation of thermography. There are many points of view on abnormal temperature changes in the skin. The American Medical Association said that asymmetry is the most important factor to consider in reading the thermography, and thus there are difficulties in determining when the patient has a symmetrical lesion.[13] When using contact-type liquid crystal thermography, abnormal ΔT is reported from 0.3°C[14] to 1.0°C.[15] When using computerized thermography, abnormal ΔT is reported from 0.3°C[16,17] to 0.62°C.[18,19] In the buttocks and legs, the abnormal ΔT in 99% confidence interval was from 0.1°C to 0.4°C, which was measured in 78 sectors of 50 normal controls.[20] In the areas of the arms and neck, this study showed that the abnormal ΔT ranges from 0.1°C to 0.3°C at each sector in 99% confidence interval, which was similar to or less than the thermal

Table 8. Sectors of Significant Thermal Change in CDH $C_{6/7}$

	S13-S41		S16-S44		S20-S48		S21-S49		S22-S50		S23-S51	
	M	T	M	T	M	T	M	T	M	T	M	T
Control	.06	2.14*	.04	−2.34*	.16		.06	3.92	.18		−.12	$-3.21^{\dagger}$
$C_{6/7}$	.38		.42		−.46		−2.14		−.70		1.33	

	S25-S53		S26-S54		S27-S55		S68-S95		S71-S98	
	M	T	M	T	M	T	M	T	M	
Control	.28	2.02*	.09	2.08*	.16	2.11*	.08	$3.17^{\dagger}$	.01	$-2.91^{\dagger}$
$C_{6/7}$	−1.08	1.06	−1.19	1.44	.73					

	S75-S102		S76-S103		S77-S104		S81-S108		S82-S109	
	M	T	M	T	M	T	M	T	M	T
Control	.08	$-3.04^{\dagger}$	.05	$2.84^{\dagger}$	.02	$-2.73^{\dagger}$	−.09	2.38*	−.01	2.23*
$C_{6/7}$	2.08		−.63		.68		.87		.42	

M, mean; T, t-value.
* t-test $p<0.05$.
† t-test $p<0.01$.

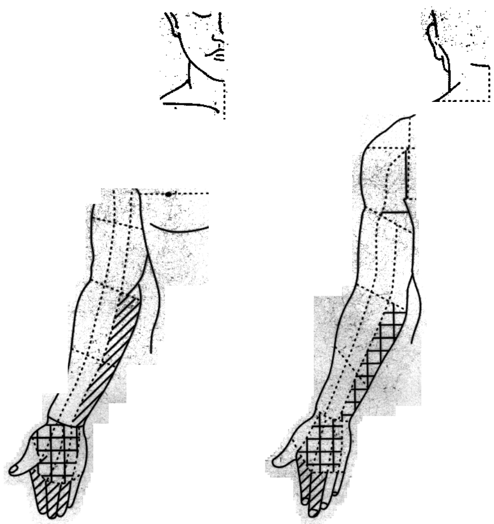

Fig. 10. The areas of significant thermal change in CDH $C_{6/7}$. The areas include the ulnar and palmar regions.

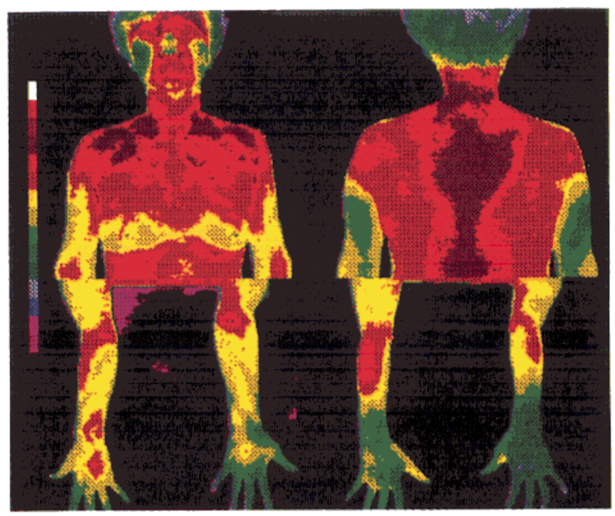

Fig. 11. Typical DITI of the $C_{6/7}$ CDH patient, which shows hypothermic change along the previously mentioned area as in Fig. 10.

differences from previous reports. We divided and checked the temperature of many small sectors and these might make the abnormal thermal differences to a lesser degree. These criteria could be used to detect the thermal asymmetry of the neck and arms if the points of measurement were exactly symmetric.

There are some stable sectors of small thermal differences, which include those areas closer to the center of the body that show the core temperature, 36.5°C, and these sectors show abnormal thermal differences when minimal ΔT is 0.1°C or 0.2°C. The more distant from the center of the body, the larger

Table 9. Sectors of Significant Thermal Change in CDH $C_{7/T1}$

	S10-S38		S13-S41		S16-S44		S58-S85		S59-S86	
	M		M	T	M	T	M	T	M	T
Control	.19	2.38*	.06	2.32*	.04	2.31*	.07	2.90	.16	−3.02†
$C_{7/T1}$	.45		.50		.60		.64		1.73	
	S61-S88		**S62-S89**		**S63-S90**		**S65-S92**		**S66-S93**	
	M	T	M	T	M	T	M	T	M	T
Control	.25	2.81	−.14	2.42*	.08	2.86†	.05	2.89†	.06	2.74
$C_{7/T1}$	−.25		−.41		−.55		−.90		.65	

	S68-S95		S69-S96		S71-S98		S72-S99	
	M	T	M	T	M	T	M	
Control	.08	2.92†		2.52	.01	2.04*	.10	−2.17*
$C_{7/T1}$	1.05		.70		−.44		.50	

M, mean; T, t-value.
* t-test $p<0.05$.
† t-test $p<0.01$.

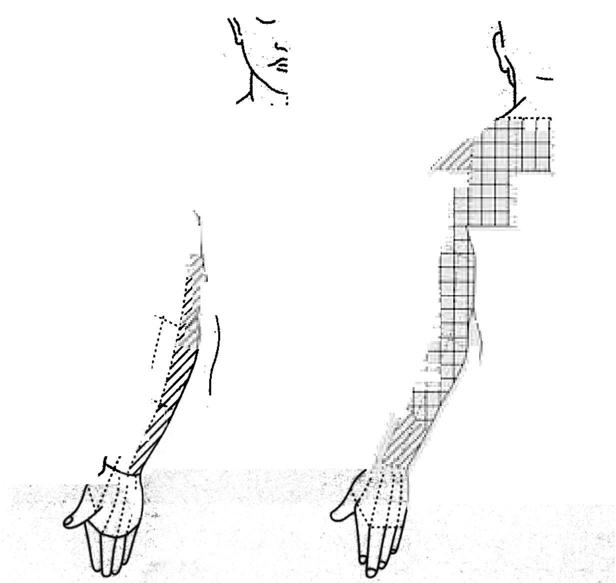

Fig. 12. The areas of significant thermal change in CDH $C_{7/T1}$. The areas include the dorsal aspect of the arm and upper back.

Fig. 13. Typical DITI of the $C_{7/T1}$ CDH patient, which shows hypothermic change along the previously mentioned area as in Fig. 12.

ΔT is significantly abnormal. The palm, dorsum of the hand and fingers are the farthest from the center of the body with the thinnest in the body. So these sectors are the coolest areas as per mean temperature and the significant minimal abnormal ΔTs range from 0.3°C.

Thermatome was defined and it has been used as the areas of skin vasculature associated with autonomic nerve by Pierre LeRoy since 1980 and was supported by Hobbins in 1983.[19] The sympathetic paravertebral ganglion controls the circulatory system of the skin. The peripheral spinal nerve has the component of autonomic nerves about 8 to 35%, and all organs receives from spinal nerves are controlled by the autonomic nerves. So the distributed areas of one peripheral spinal nerve show the thermatome, but it is not exactly the same in all cases. And dermatome, myotome and sclerotome, which were developed from the same somite, have the same neural circuit and have a common referral pathway.[19,21] In human study, thermatomes of the lumbosacral nerve roots were revealed by comparison with normal controls and lumbar disc herniation patients.[20] Investigations found that the lumbosacral thermatome is somewhat wider in area than the dermatome.

Dermatomes of rat limbs were determined by electrical stimulation of each nerve root after intravenous Evans blue injection.[22] Reseachers found the antidromic stimulation of sensory c-fiber in spinal nerves and the exact dermatomes of the rat limbs. Based on this study, researchers took the thermography with electrical stimulation of the L_5 spinal nerve root. It revealed the area of thermatomal change after L_5 nerve root stimulation. They pointed out that the thermatome of L_5 is wider than the dermatome of L_5 in rat.[23]

Thermatomal changes in this study showed a larger area than the area including sensory dermatomes[24] and sympathetic dermatomes[25] in each level. This study showed that the factors of skin temperature control include the factors making the dermatome and other general functions and autonomic functions.

In the case of the lumbar spine, various studies showed the clinical effectiveness of thermography. Thermography is effective in detection of the objective pain site and the evaluation of postoperative pain.[26] After the identification of lumbosacral thermatomes,[20] thermography has been used effectively in the detection of a symptomatic disc in multiple lumbar disc herniation cases.[27] In the cervical spine, there have been several studies with thermograms,[11,14,28] and this is the first documentation for cervical thermatomal changes in CDH.

Before this study, we could only detect the thermal asymmetry of the arm in CDH, but we could not determine the level of CDH. Preoperative thermography can show the sectors of significant thermal difference, and it can be used to identify the level of CDH by analysis of the thermal change pattern of thermography. It may also be helpful to detect the symptomatic level in multiple CDH patients.

In summary, this study used the DITIs of 50 normal controls and 115 single level one-side CDH patients. We made the temperature distribution of normal contorls, a statistically significant thermal difference in each sector, and the areas of thermatomal change of the $C_{3/4}$, $C_{4/5}$, $C_{5/6}$, $C_{6/7}$, and $C_{7/T1}$ in CDH. Temperatures in the control group were warm at the proximal part of the arm, cubital fossa, etc. and cool at the hand and fingers. Minimal abnormal thermal differences in the arm showed sectors of 0.1°C, 0.2°C or 0.3°C. Thermatomal change areas of the $C_{3/4}$, $C_{4/5}$, $C_{5/6}$, $C_{6/7}$, and $C_{7/T1}$ in CDH were made statistically under $p<0.01$ and $p<0.05$. This study will be used in CDH patients to detect the exact areas of thermal change and to diagnose the level of disc protrusion with preoperative DITI.

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