MEDICORE

Show Me the “Pain”

With IRIS-5000

Clinical solution for the pain diagnosis with thermography

“ The superior physician prevents disease,

The mediocre physician treats impending disease,

The inferior physician treats real disease.”

-Huang Dee: Nai-Ching (1st Chinese medical text) 2600 BC

INDEX

- **INFORMATIONAL REPORT OF THE COUNCIL ON SCIENTIFIC AFFAIRS**

- John H. Moxley, III, M.D., Chairman

Thermography is a safe adjunctive physiological procedure which may be useful in the diagnosis of selected neurological and musculoskeletal conditions. Thermography is noninvasive and does not involve the use of ionizing radiation. Thermography may facilitate the determination of spinal nerve root and distal peripheral nerve dysfunction. Thermography also contributes to the evaluation of possible autonomic nervous system dysfunction and of spinal disorders.

Thermography may be useful in documenting peripheral nerve and soft tissue injuries, such as muscle and ligament sprain, inflammation, muscle spasm, and myositis. Thermography is helpful in the diagnosis of reflex sympathetic dystrophy and can be used to follow the course of patients after spinal surgery.

- **JOINT COUNCIL OF STATE NEUROSURGICAL SOCIETIES of the AMERICAN ASSOCIATION OF NEUROLOGICAL SURGEONS and the CONGRESS OF NEUROLOGICAL SURGEONS**

- Lyle Leibrook, M.D.

Prospective studies have shown the excellent sensitivity and good correlation of thermography with other imaging methods. A high correlation of 84% has been demonstrated in studies comparing thermography and CT scanning of patients with low back pain and sciatica. Surgical treatment has also shown similar high rates of sensitivity. A large study of 805 patients with upper and low back pain confirms good correlation between thermographic evaluation and myelography, CAT scanning and EMG. The two objective tests for documentation of sensory radiculopathy, thermography and somatosensory cortical evoked potential's, show equal sensitivity in the diagnosis of clinical lumbosacral radiculopathy.

1. General Introduction of Thermography

1.1 Definition of Clinical Thermography

In simplest terms, thermography means " Picture of Heat ".

Clinical Thermography is a diagnostic imaging procedure that detects records, and produces an image of a patient's skin surface temperature using infrared radiation emitted by the surface of that body at wavelengths between 0.8μm and 1.0mm.

1.2 Thermographic Benefit

3N

Thermography is a **Non Invasive** test,
has **No Risk**, and
causes **No Pain** to the patient.

1.3 Clinical Usefulness of Thermography

1. Pain Diagnosis – Shows pain objectively with visual images
2. Screening (early detection) – Breast tumor, Rheumatic disease etc…
3. Treatment Evaluation – By comparing Pre- and Post- images
4. Discrimination of Malingering or Compensation –Traffic accident patient, Worker's compensation program

1.4 Brief History

- 400 B.C., Hippocrates: examined body heat by applying mud to patient skin (The first examination of body heat)
- 1592 A.D., Galileo: developed the first thermoscope, a temperature measuring instrument
- 1800, William Herschel: discovered infrared
- 1840, John G. Herschel: studied image processing technique using infrared rays, named it Thermograph
- 1871, Wunderich: discovered medical thermometer
- 1956, Lawson: observed change in body heat of breast cancer tissue by using evaporograph
- 1982, Pochaczevsky & Wexler: made diagnosis of lesion in nerve root, such as herniation of lumbar vertebra disk by using a contact-type liquid crystal temperature imaging instrument
- 1985, Mills: examined body heat distribution for each part of legs of patients with stenosis in lumbar vertebra cavity

1.5 Applications

Major Applications	**Pain Diagnosis** **Treatment Evaluation** **Breast Screening**
Neural Disease	Neuralgia, Chronic & Acute back pain, Carpal tunnel syndrome, Disc&Spinal nerve injury, Spinal stenosis, Peripheral nerve injury, Causalgia, Reflex sympathetic dystrophy, Autonomic nerve injury, Hypohydrosis, CVA, Facial palsy, Migrain, Sensory nerve abnormality
Musculoskeletal Disease	Myofascial pain syndrome, Arthritis, Brachial plexus injury, Rheumatoid arthritis, Musculoligmentous spasm Sprain & Strain, Myofascitis
Cardiovascular Disease	Deep vein disease, Varicose vein, Thrombosis, Peripheral vascular disease, Burger's disease, Raynaud's syndrome, Vascular inflammation disease
Cancerous Disease	Breast cancer screening test, Thyroidal & Parathyroidal disease
Other Applicable Fields	E.N.T / Dental Disease, Urological Disease, Dermatological Disease,

2. Physiological Basis

- The Skin is the center of body temperature regulation.
- Skin temperature regulation system can be divided to following two mechanisms: CNS control and ANS response
- Healthy subjects show right and left symmetry in the skin temperature distribution.

2.1 Skin as a temperature-regulating system

The skin is the largest organ of the body. One of its major functions is to maintain homeostasis of body temperature.

The skin contains microneurovasculature networks, which are controlled by autonomic nervous system. Skin temperature thus cannot be regulated at will, but can be changed as a reflex response.

2.2 Mechanisms of skin temperature regulation

General

1. Localized muscular action
2. Antidromic stimulation of sensory nerve
3. Activation of sinuvertebral nerve

Autonomic system

1. Stimulation of the ‘spinal parasympathetic’ nerves
2. Stimulation of sympathetic vasodilatory system
3. Sympathetic vasoconstriction
4. Segmental regulation by somatosympathetic reflex

2.3 Symmetry of skin temperature in healthy individuals

Central control of skin temperature affects both sides of the body uniformly and simultaneously, resulting in symmetry of thermal patterns. Therefore, in a healthy subject, there is a contralateral(right and left) symmetry in the skin temperature distribution, and an asymmetry above a certain level is a strong indicator of an abnormality.

In an exam of 32 healthy subjects, it is found that the highest skin temperature on the body was the forehead (34.5℃) and the lowest was at the toes (27.1℃). However, it has been proved that the temperature distribution is more important than the absolute temperature.

3. Diagnostic Criteria

- Thermal symmetry of the skin temperature is an indicator of normal physiology of human body.
- Abnormality of physiologic function of body can be diagnosed with left and right skin temperature differences.
- Cranial-Caudal relationship, which shows normal temperature difference of upper and lower body, also can be used as a diagnostic criterion.

3.1 Thermal Symmetry of the Skin

As mentioned earlier, human body temperature displays symmetrical thermal pattern. It is an important factor to determine physiological abnormality with thermography. Objective data of temperature difference can be achieved by using ROI (Region of Interest). ROI would be a great help for an accurate and objective diagnosis.

3.2 Guidelines for diagnosis of thermal asymmetry

In a study of body temperatures in a series of healthy subject, the overall average temperature difference was only 0.24℃. The temperature difference differs in each part of the body. Various guidelines have been recommended for diagnosis of thermal asymmetry. Some reported the mean temperature difference above 0.3℃ as a significant value and some above 0.6℃.

Generally, in Korea, the mean temperature difference greater than 0.6℃ is considered to be abnormal.

When greater than 1.0℃, there is no doubt of functional abnormality.

<Table 1. Contralateral Skin Temperature Differences in Normal Subjects>

(Uematsu, 1986)

Skin-temperature Differences between Sides of the Body			
Body segment	Cutaneous Sensory nerves and segments measured	Mean average temperature differences	
		(°C)	S.D.
Forehead	Trigeminal Nerve(V-1)	0.12	0.093
Cheek	Trigeminal Nerve(V-2)	0.18	0.186
Chest	Intercostal(T1-T7)	0.14	0.151
Abdomen	Intercostal(T7-T10)	0.18	0.131
Neck(Posterior)	Cervical(C2-C5)	0.15	0.091
Thoracic, paraspinal	Post-Cutaneous(T2-T12)	0.15	0.092
Lumber(Back)	Dorsal div.spinal(T11,12,L1,2,3,S1,2,3)	0.25	0.201
(Trunk Average)		(0.17)	(0.042)
Scapula	Dorsal div. spinal(T1,5)	0.13	0.108
Arm(Biceps)	Med. antebrachial(C8,T1)	0.13	0.119
(Triceps)	Dorsal antebrachial, axillary(C5-6)	0.22	0.155
Forearm(Medial)	Med. antebrachial(C8,T1)	0.32	0.158
(Lateral)	Lat.antebrachial(C5-6)	0.23	0.198
Palm(Lateral)	Median(C6,7,8)	0.25	0.166
(Medial)	Uinar(C8,T1)	0.23	0.197
Thigh(Anterior)	Ant. fem. cutaneous(L2-3)	0.11	0.085
(Posterior)	Posterior cutaneous(S1,2,3)	0.15	0.116
Knee(patellar)	Ant. fem. cutaneous(L2,3)	0.23	0.174
Popliteal	Post. fem. cut., Com. Peron.(L4-5,S1-2,3)	0.12	0.101
Leg(Anterior)	Saphenous, sup. Peroneal(L3,4,S1-2)	0.31	0.277
Calf	Sural, Saphenous(L3,4,S1-2)	0.13	0.108
Foot(dorsal)	Peroneals(L4-5,S1)	0.30	0.201
Heel	Tibial(S1-2)	0.20	0.220
(Extremities,Average)		(0.20)	(0.073)
Finger(Tips),*Average	Median & ulnar(C5,6,7,8,T1)	(0.38)	(0.064)
Toe(Tips), **Average	Median, lateral, planter(L4,5,S1-2)	(0.50)	(0.143)

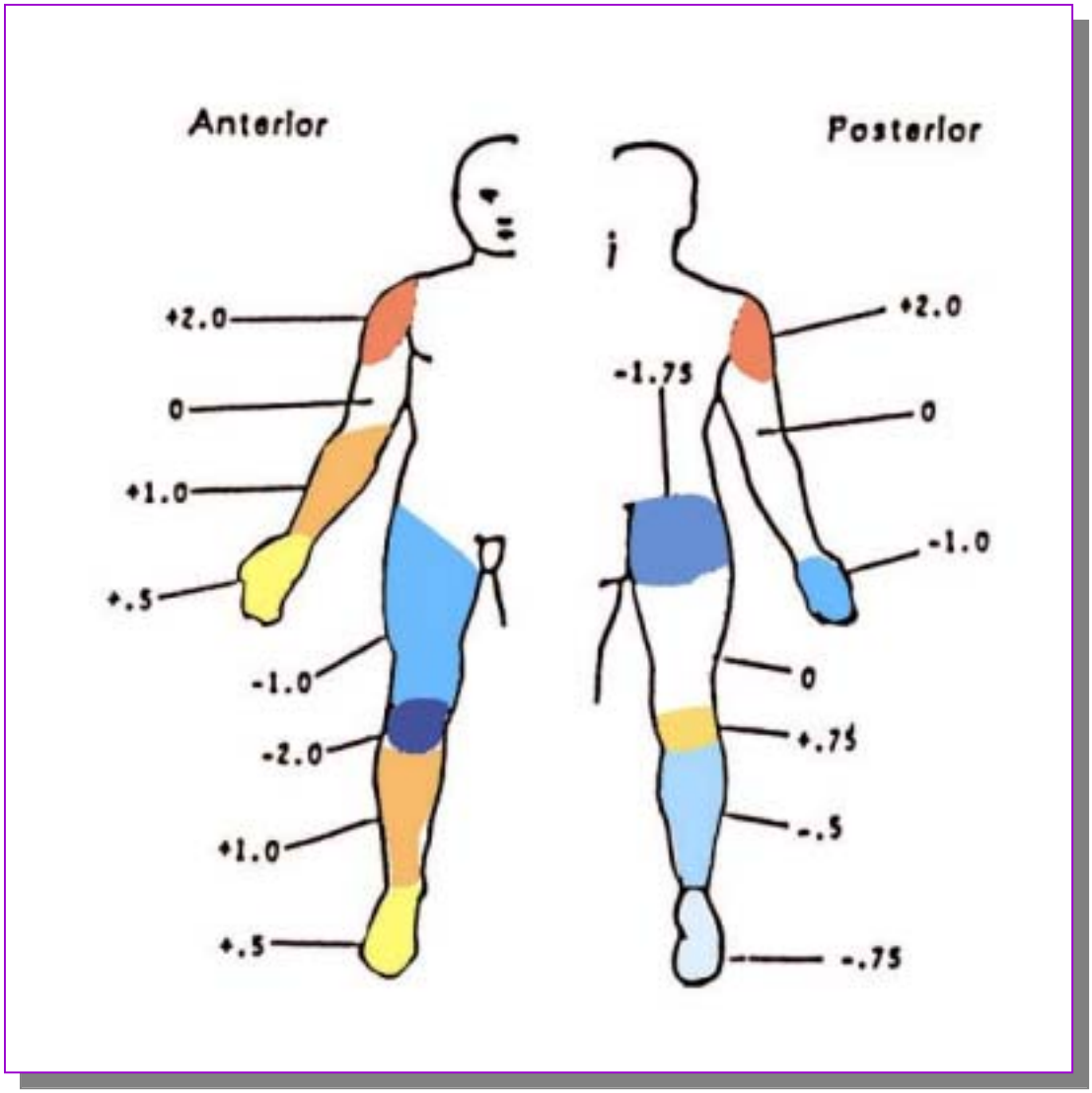
* Five segments, but only average is given here

** Five segments(big toe and four others), but only average is given here

3.3 Cranial-Caudal Relationship

Displaying temperature difference between upper and lower body of anterior and posterior by considering anterior brachial and posterior thigh region as 0 ℃

<Fig 1. Cranial-Caudal Relationship>



4. Guidelines for Thermal Image Interpretation

4.1 The Quantitative Values of Heat

- The mean temperature difference (ΔT)

Objective data of temperature difference can be achieved by using ROI (Region of Interest). These quantitative values are used to identify whether the subject is in normal condition or abnormal condition.

4.2 The Color of Heat

- Red (Bright) or Blue (Dark)

Certain groups of Color in thermography generally have their own meanings.

- Red (Bright) Side Color: acute stage, inflammatory disease and muscle activity (overuse) related disorders
- Blue (Dark) Side Color: chronic stage, neural disease

4.3 The Shape of Heat

- Localized, Regional or Patternized (shows specific distribution)

Different shapes of heat appear in thermal images and are used as a diagnostic standard of thermography. Three different shapes are discussed in this paper and used for proper diagnosis.

- Localized shape: Spot type. Commonly due to local muscle activity
- Regional shape: Referred type. Somatic or visceral induced disorders
- Patternized shape: Thermatome. Neuropathic pain

4.4 Normal Thermal Pattern of the Skin (NTP)

1. **Contralateral symmetry of thermal pattern**

2. **Heat continuity on the back midline**

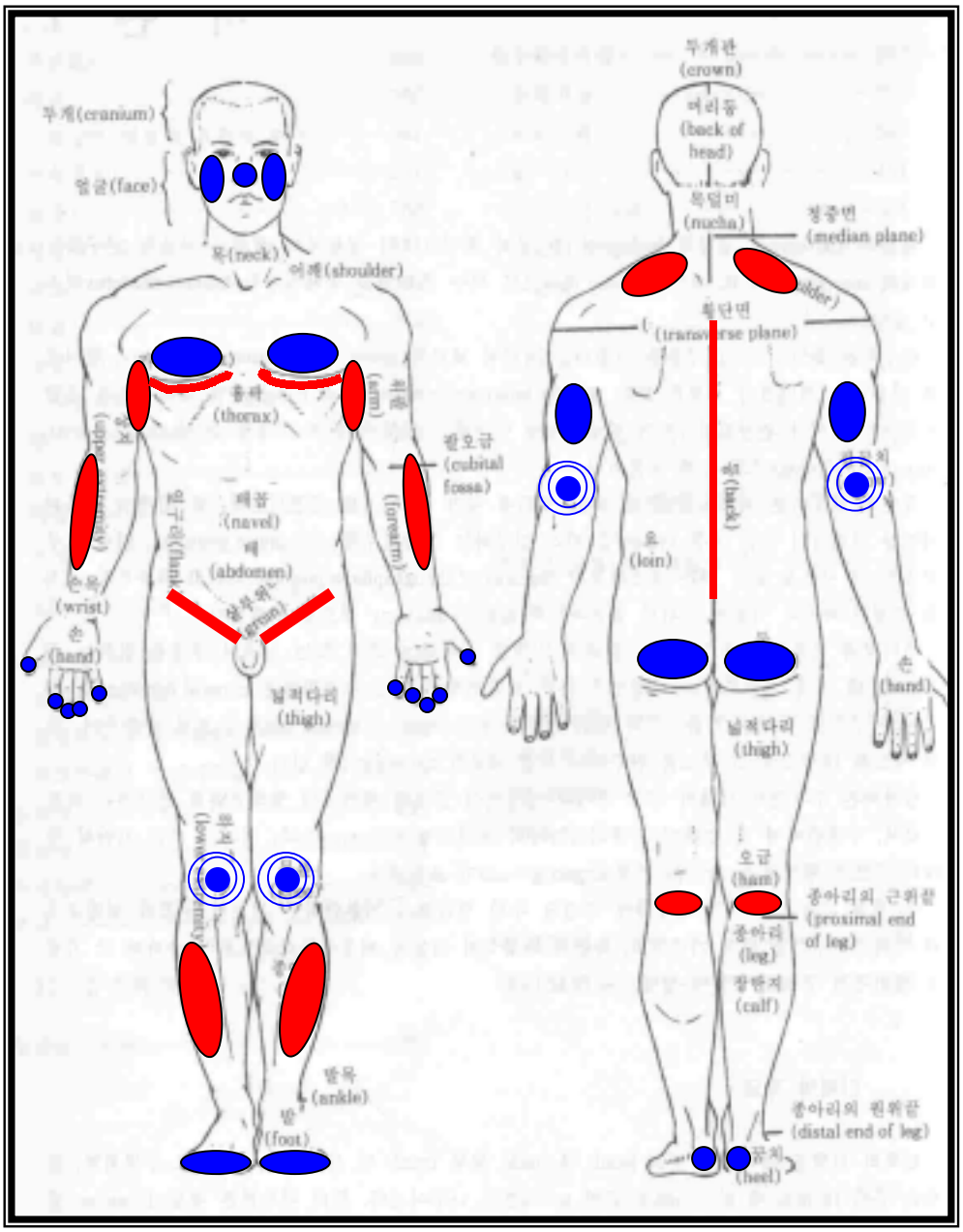
3. **Hyperthermia on** : 1) The muscles
   (esp. Trapezius, Brachioradialis, Anterior tibia etc.)
   2) Overlapped skin areas
   (esp. Ham, Under the breast, Axilla, Groin(Inguen))

4. **Hypothermia on** : 1) Joint area (Elbow, Knee)
   2) Distal area
   (Finger tips (palm side), Toe tips, Cheek, Heel, Nose)
   3) Fat area (Breast, Buttock, Brachial region)

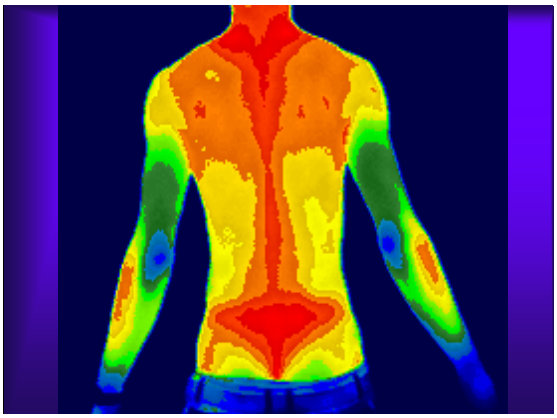
5. **A contour line on joint bone areas**

6. **Middle range color distribution on the region except areas mentioned above**
   (Middle range color: the colors except the lowest and the highest color in the image)

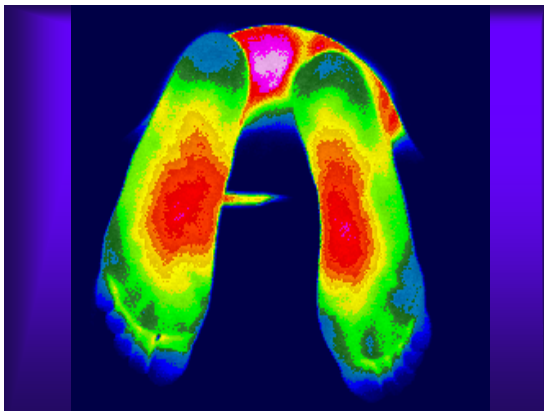
<Fig 2. Normal Thermal Pattern of the skin>



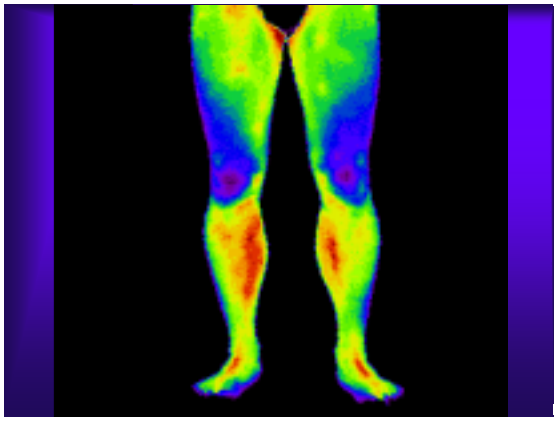
<Referral Normal Body Images>



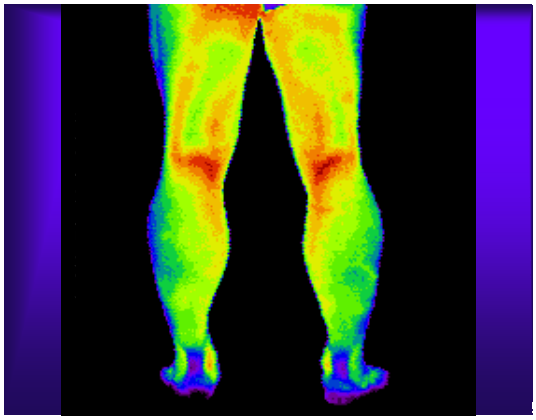
Back



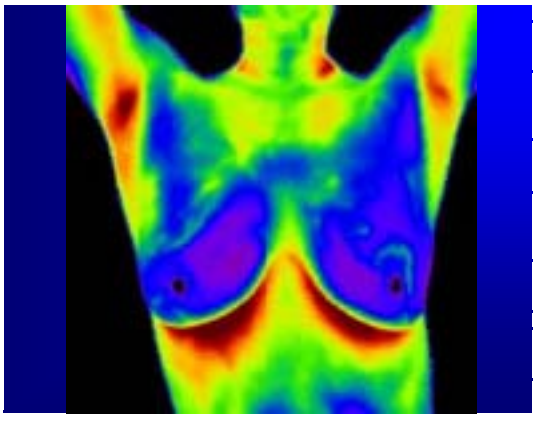
Plantar



Anterior Low Extremity

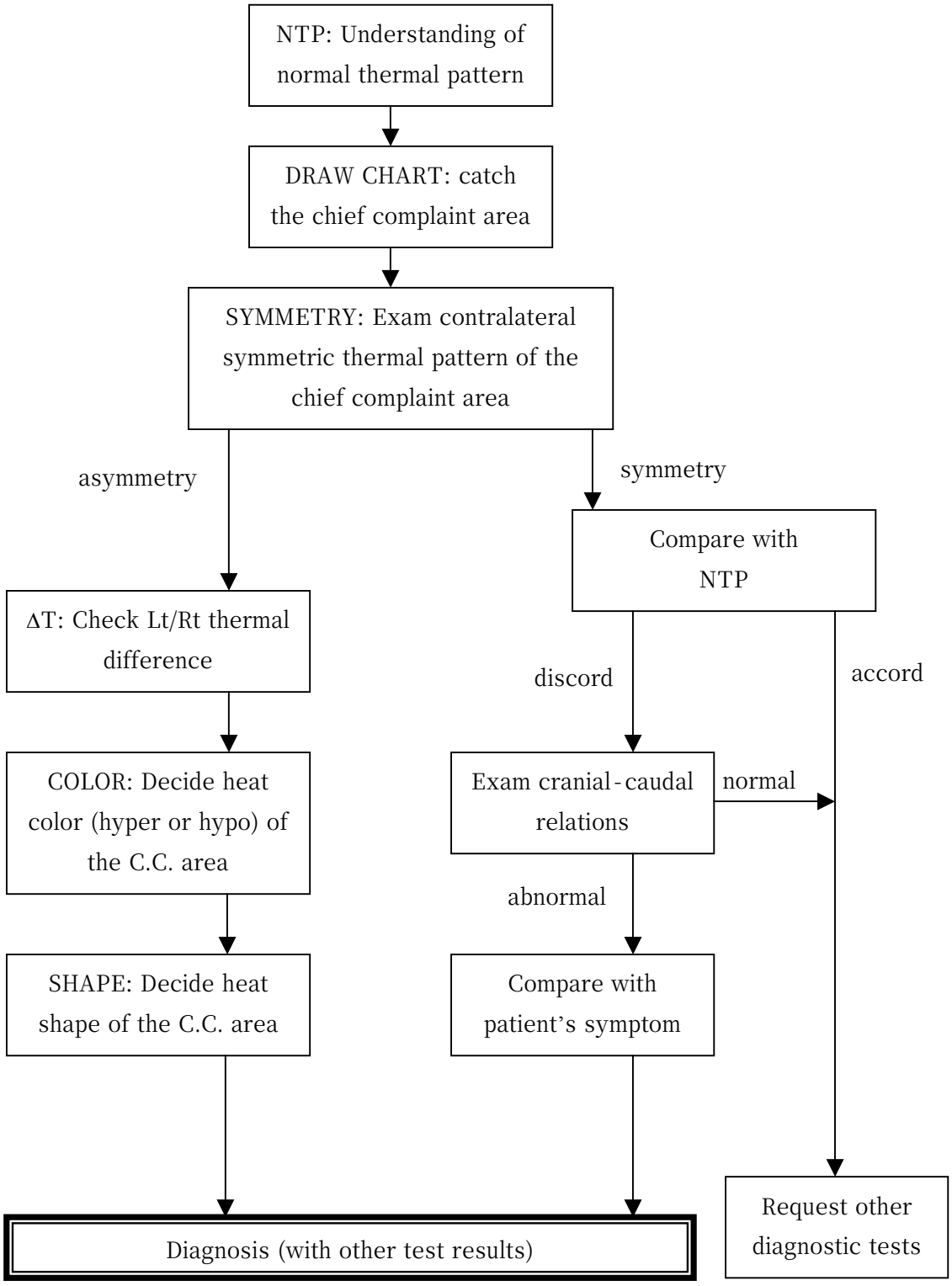


Posterior Low Extremity



Breast

4.5 Flow Chart for Interpretation



5. Thermography and Pain Diagnosis

The differential diagnosis of pain has long been a dilemma as the documentation of pain has been based mostly on subjectivity. Thermography provides objective and quantitative data of pain thus playing an important role in pain diagnosis.

<Thermographic Pain Classification>

Two basic approaches to classify pain in thermography can be used;

1) **Acute or Chronic**
2) Categorization by involved part of the body
   - **Neural disease – neuropathic pain**
   - **Musculoskeletal disease**
   - **Inflammatory disease**
   - **Vascular disease**

5.1 Acute or Chronic?

Acute and chronic pain may display different color in thermographic images. In general situation, “red (or bright)” color stands for “acute” and “blue (or dark)” stands for “chronic”. Normally the warmer the object, the brighter the color of the image.

5.2 Categorization

5.2.1 Neuropathic Pain

It is estimated that Neuropathic pain affects 2-4 % of the general population.

Neuropathic pain (from the Greek *neuro,* meaning nerves, and *pathy,* meaning abnormality) is the pain initiated or caused by a primary lesion or dysfunction in the nervous system. (IASP: International Association for the Study of Pain)

There are various types and causes of neuropathic pain; but here are listed some of pain syndromes which have great diagnostic values with thermography.

Types	Common causes
Mononeuropathy	Amputation stump pain Causalgia Diabetes mellitus Neuroma Plexus avulsion Postherpetic neuralgia Traumatic Vasculitis
Mononeuropathy multiplex	Diabetes
Polyneuropathy	Alcohol Nutritional neuropathy Chemotherapy Diabetes Ehrler danlos syndrome Fabre disease HIV Vitamin deficiencies
Cancer	
Neurosyphilis (Tabes)	
Trigeminal neuralgia	

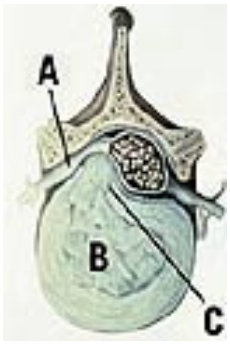
<Table 2. Disease in which neuropathic pain may occur>

5.2.1.1 Intervertebral disc herniation

Several reports have appeared describing the high accuracy, sensitivity, and specificity of thermography in evaluation of lumbar and cervical disc disorders.

Moreover, thermographic imaging has a positive correlation with other diagnostic studies (EMG, CT, myelogram, MRI) in patients with disease associated with spinal nerve root fiber abnormality

- **Lumbar disc herniation**



As a disc degenerates, it can herniate (the inner core extrudes) back into the spinal canal. The weak spot in a disc is directly under the nerve root, and a herniation in this area puts direct pressure on the nerve, which in turn can cause pain to radiate all the way down the patient's leg to the foot.

<Lumbar disc herniation>
A: Exiting nerve root
B: disc
C: torn outer annulus

Approximately 90% of disc herniations will occur at L4- L5 (lumbar segments 4 and 5) or L5- S1 (lumbar segment 5 and sacral segment 1), which causes pain in the L5 nerve or S1 nerve, respectively.

Distribution of disc herniations and their frequency ->

- **Cervical disc herniation**

When cervical disc herniations occur, most of them will extrude out to the side of the spinal canal and impinge on the exiting nerve root at the lower level (e.g. C6 at C5-C6)

<Sagittal view of the cervical spine>
Base of the brain is at the top with the spinal cord extending down from it in the spinal canal. The cervical discs are sandwiched in between the vertebral bodies.

- **Diagnosis with thermography**

Subjective symptoms of a cool or warm sensation in the arm and leg could be shown objectively by using thermography with the detection of thermal change. The area of radiating arm or leg pain is distributed within the involved dermatome (dermatomal thermatome).

For neurological problem, 'thermatome' has been used to help the diagnosis. Thermatome means the skin area linked with the autonomic nerves and has some patterns like dermatome. Therefore it helps to find the origin of the problem.

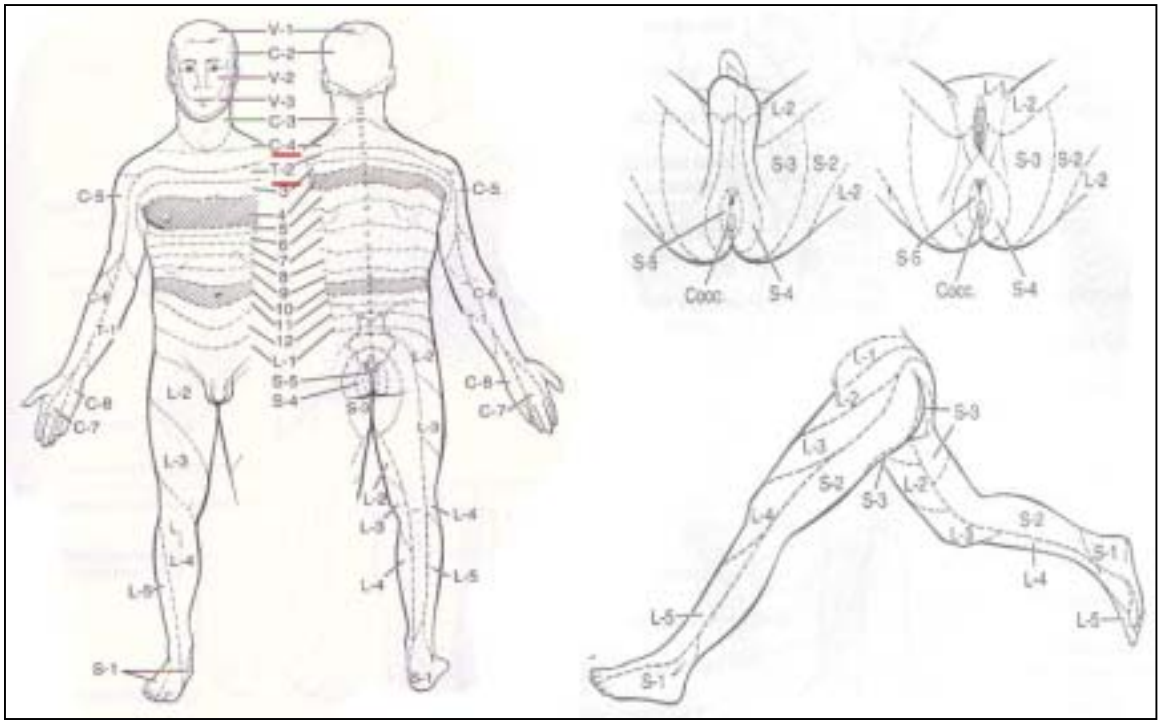
" Thermography can objectively record pain in the body thermatome areas."

- William B. Hobbins, Thermography and Pain Update 1984

++ DERMATOME ++

Dermatome means the area of skin that is supplied with afferent nerve fibers by a single dorsal spinal root

<Fig 3. Mapping of the dermatome>



+++ THERMATOME +++

1) CERVICAL

a. Measurement sectors of skin temperature

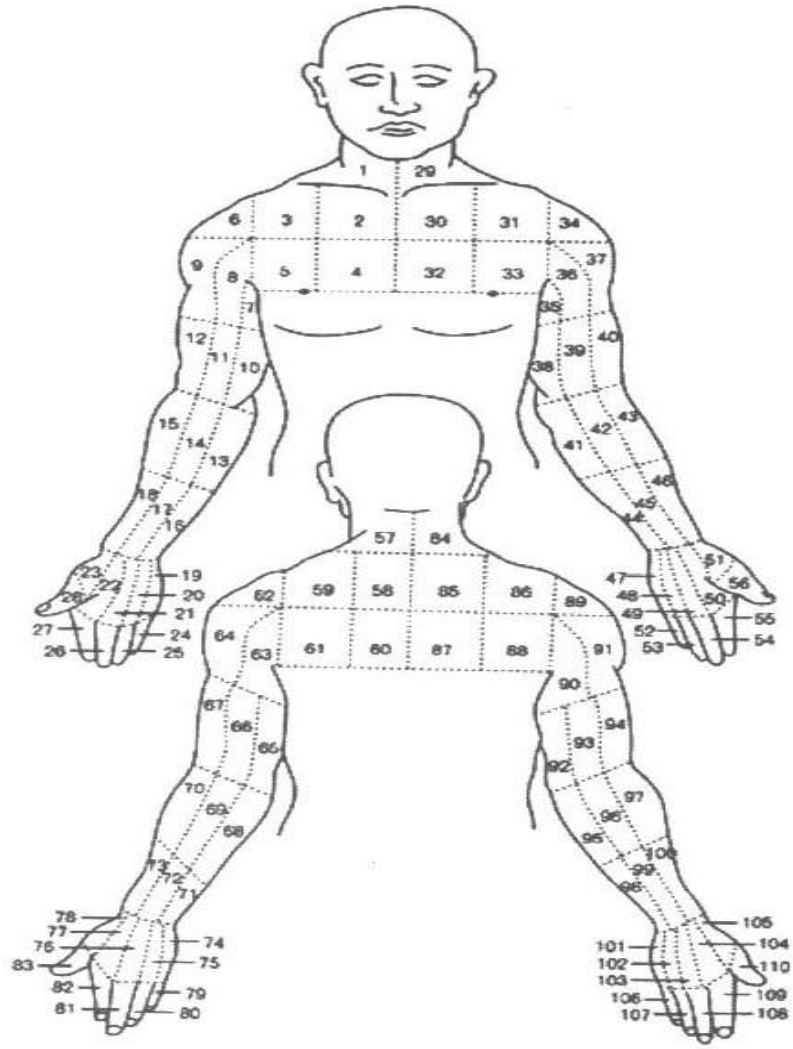


Fig 4. Measurement sectors of skin temperature. The anterior aspect of the arms and trunk has 28 sectors in each side, while the posterior aspects have 27 sectors in each side. Skin temperature was measured in each sector.

b. CDH (Cervical Disc Herniation) thermal change area (anterior, posterior)

CDH C3/4 posterior upper back and shoulder

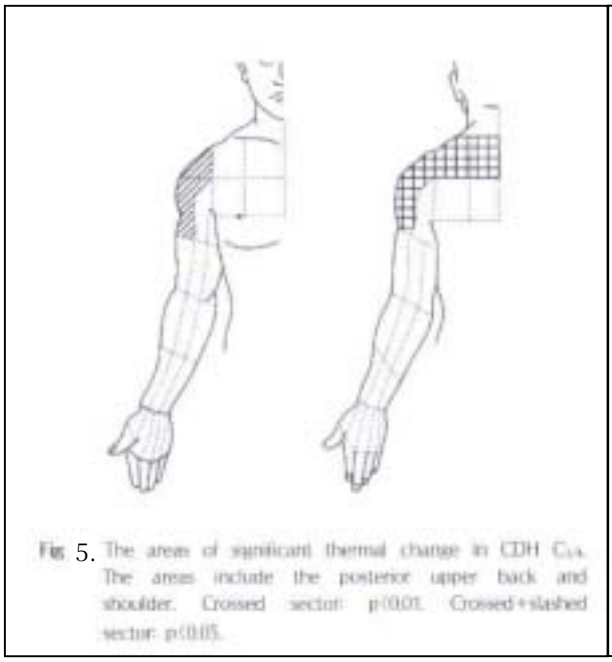


Fig. 5. The areas of significant thermal change in CDH $C_{3/4}$. The areas include the posterior upper back and shoulder. Crossed section: $p<0.01$. Crossed+slashed section: $p<0.05$.

CDH C4/5 triceps region

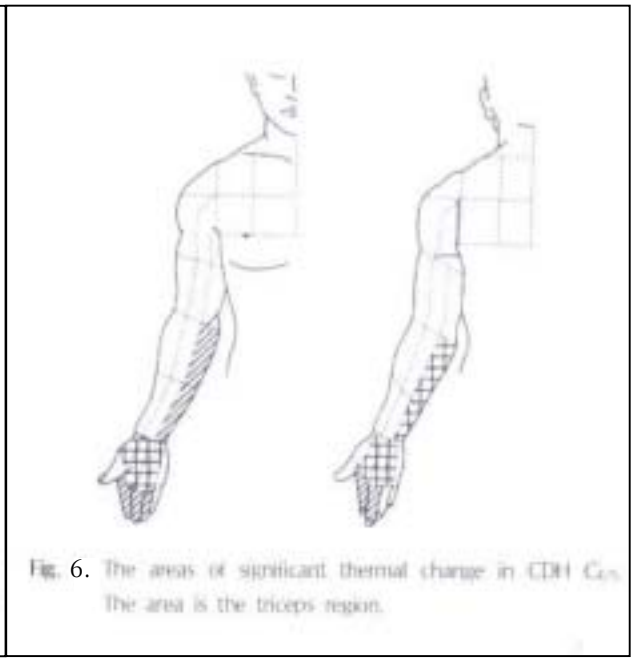


Fig. 6. The areas of significant thermal change in CDH $C_{4/5}$. The area is the triceps region.

CDH C5/6 thenar region

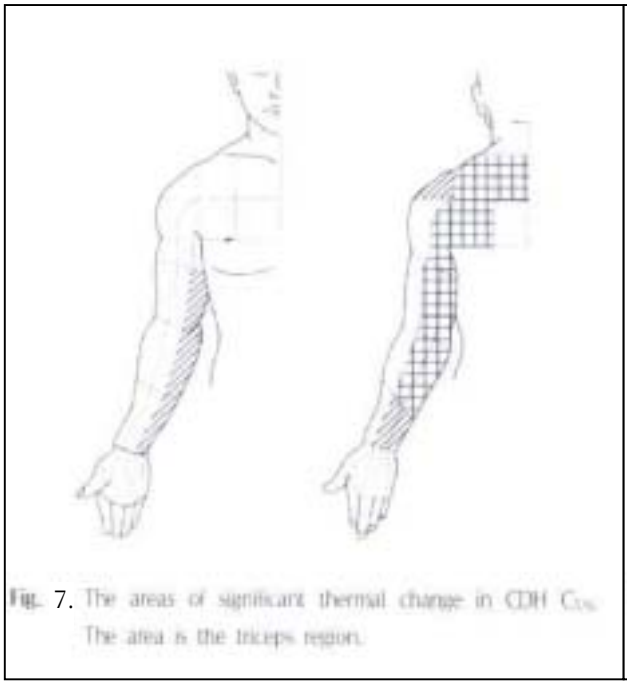


Fig. 7. The areas of significant thermal change in CDH $C_{5/6}$. The area is the triceps region.

CDH C6/7 ulnar and palmar regions

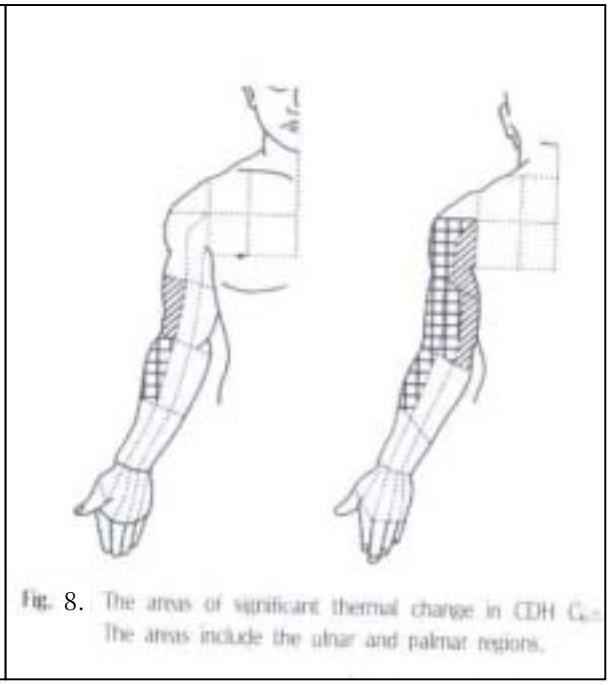


Fig. 8. The areas of significant thermal change in CDH $C_{6/7}$. The areas include the ulnar and palmar regions.

CDH C7/T1 dorsal aspect of the arm and upper back

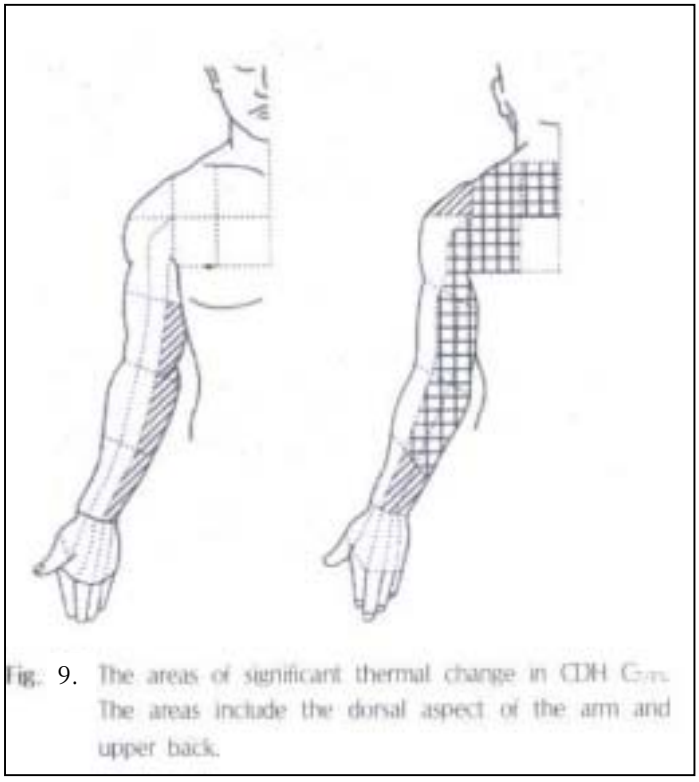


Fig. 9. The areas of significant thermal change in CDH C7/T1. The areas include the dorsal aspect of the arm and upper back.

2) LUMBAR & SACRAL

a. Measurement sectors of skin temperature

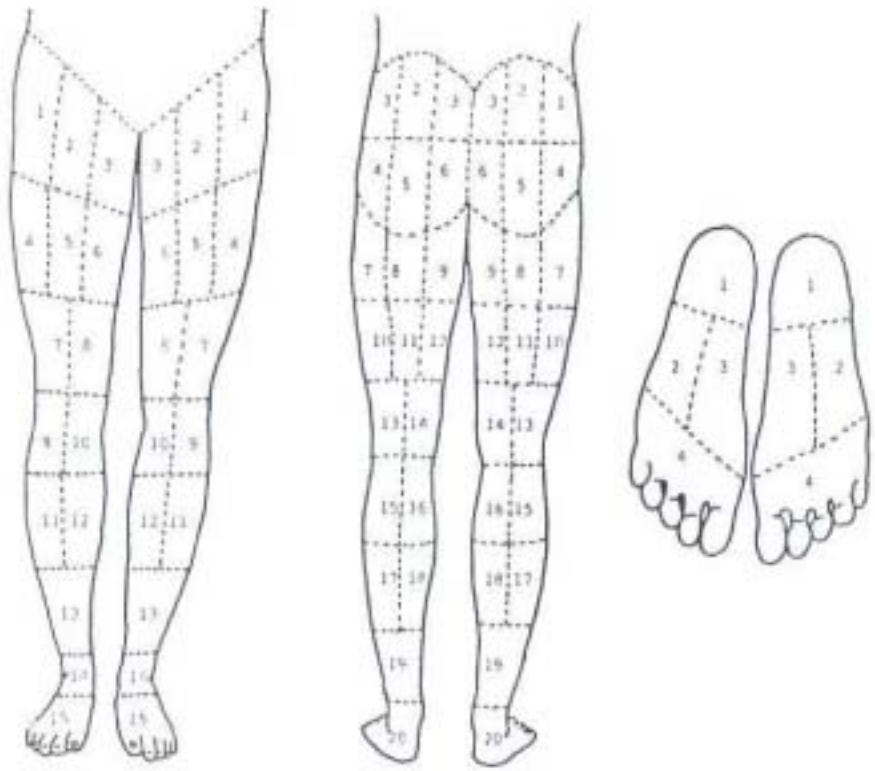


Fig. 10. Measurement sectors of the skin temperature. The anterior aspect of leg has 15 sectors in each side, while buttock and posterior aspects of leg have 20 sectors in each side, and the sole has 4 sectors in each side. Skin temperature was measured for each sector.

b. Temperature difference of each sector

Dotted area : 0.1° C, Slashed area : 0.2° C ,
Double slashed area : 0.3 ° C , Blacked area : 0.4 ° C

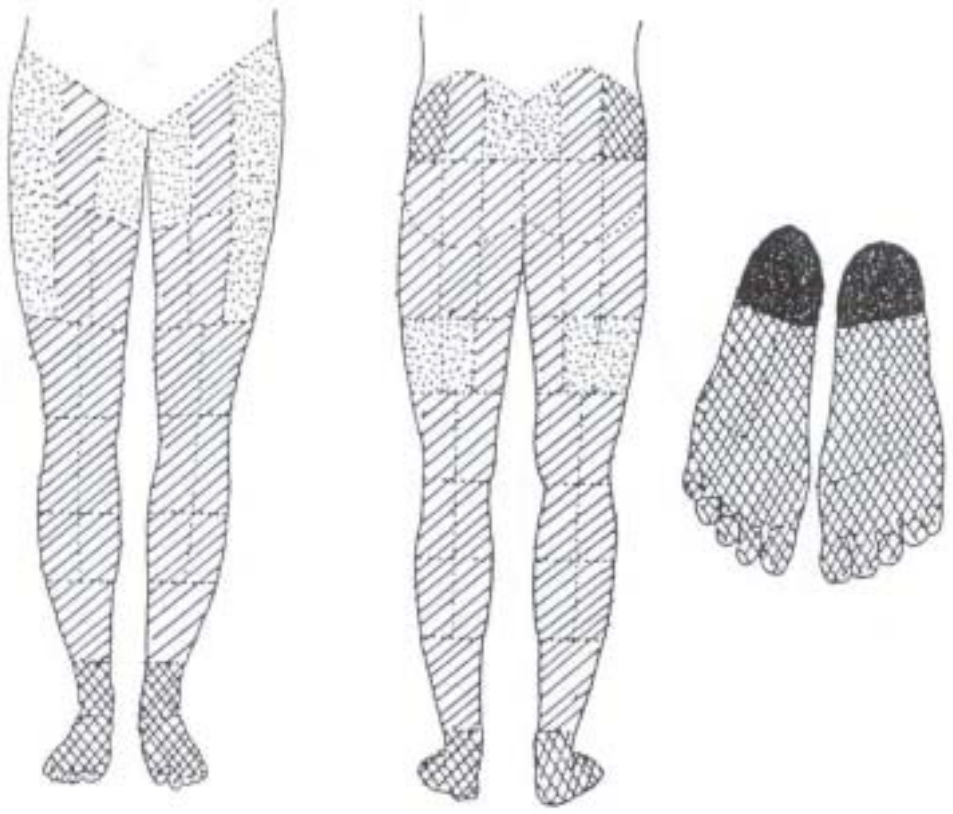


Fig. 11. Minimal abnormal thermal differences between right and left leg in DITI present with various shapes in each sector.
dotted area: These sectors can be recognized as abnormal if the thermal difference between both legs is more than 0.1℃.
slashed area: These sectors can be recognized as abnormal if the thermal difference between both legs is more than 0.2℃.
double slashed area: These sectors can be recognized as abnormal if the thermal difference between both legs is more than 0.3℃.
black area: These sectors can be recognized as abnormal if the thermal difference between both legs is more than 0.4℃.

b. Lumbar & Sacral Disc Herniation thermal change area (anterior, posterior and plantar)

Thermatome of L4 nerve root

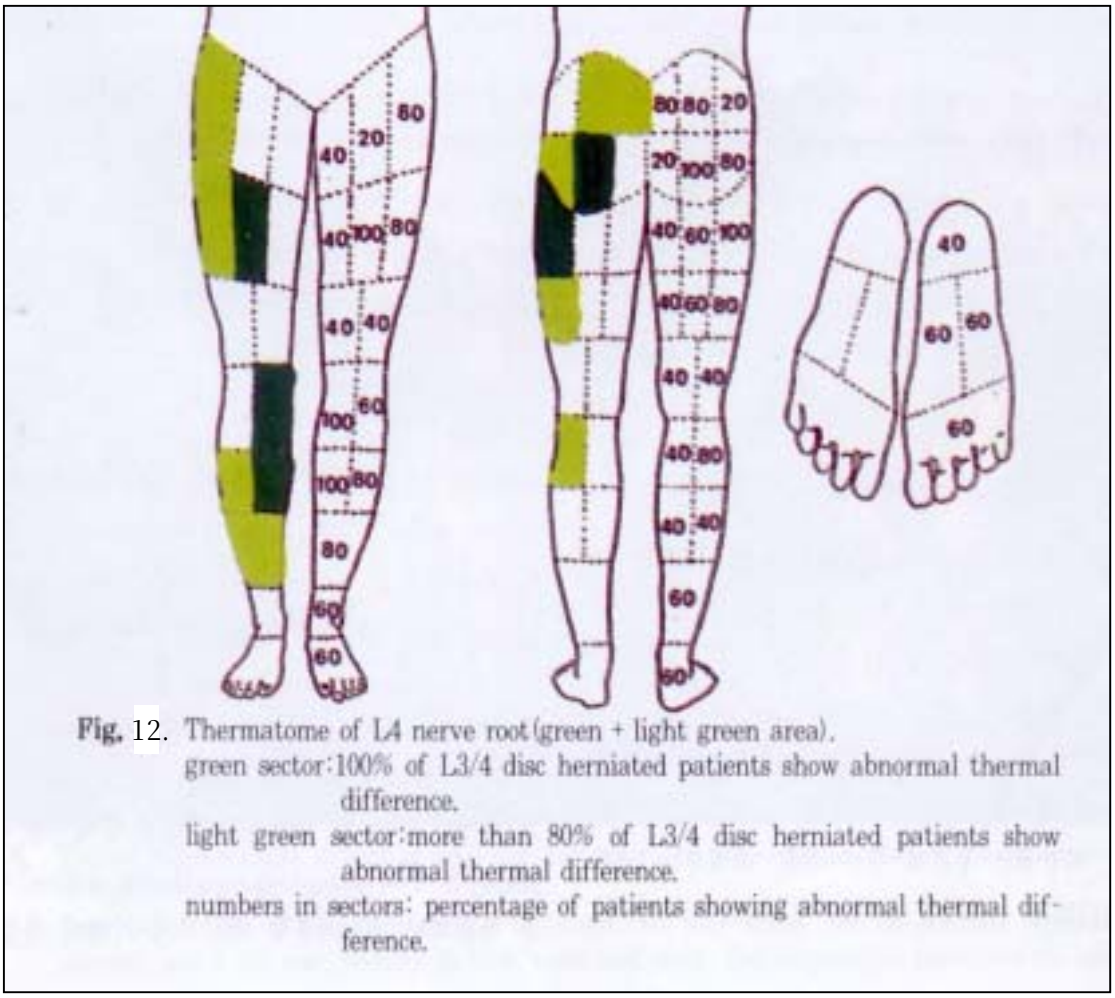


Fig. 12. Thermatome of L4 nerve root (green + light green area).
green sector: 100% of L3/4 disc herniated patients show abnormal thermal difference.
light green sector: more than 80% of L3/4 disc herniated patients show abnormal thermal difference.
numbers in sectors: percentage of patients showing abnormal thermal difference.

Thermatome of L5 nerve root

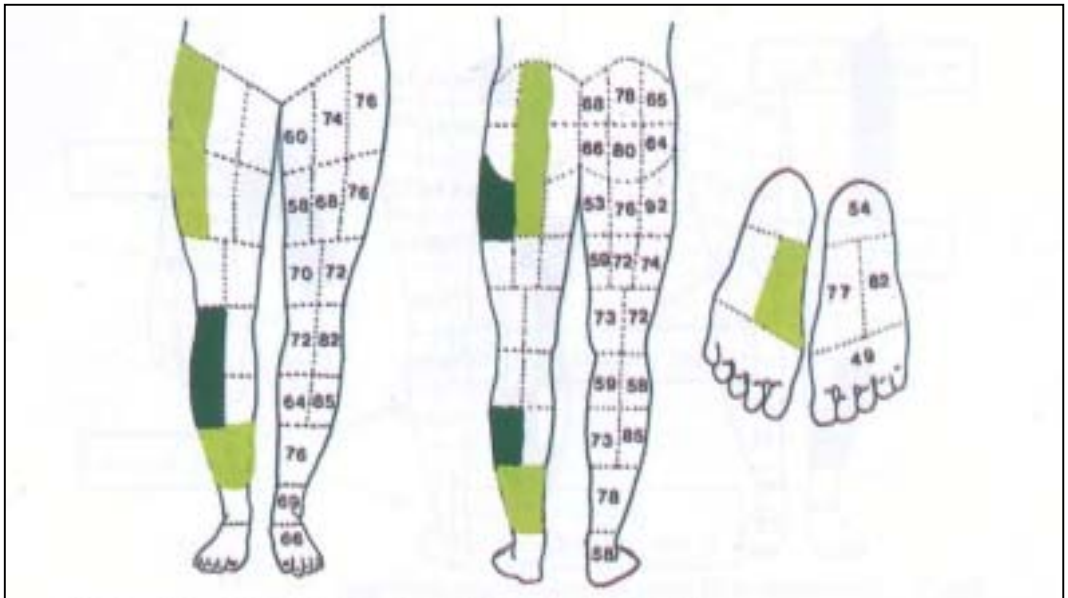


Fig. 13. Thermatome of L5 nerve root (green + light green area).
green sector: more than 85% of L4/5 disc herniated patients show abnormal thermal difference.
light green sector: more than 75% of L4/5 disc herniated patients show abnormal thermal difference.
numbers in sectors: percentage of patients showing abnormal thermal difference.

Thermatome of S1 nerve root

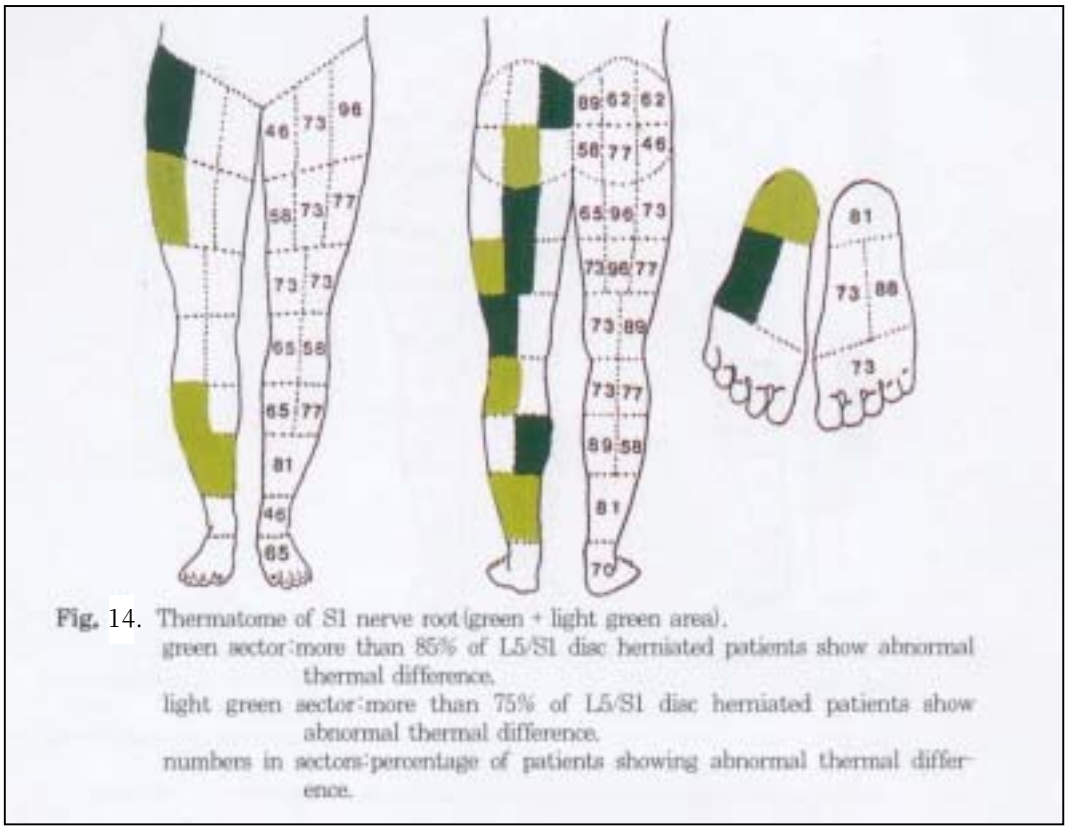


Fig. 14. Thermatome of S1 nerve root (green + light green area).
green sector: more than 85% of L5/S1 disc herniated patients show abnormal thermal difference.
light green sector: more than 75% of L5/S1 disc herniated patients show abnormal thermal difference.
numbers in sectors: percentage of patients showing abnormal thermal difference.

Diagnostic Standard

1. Hyperthermia at the anatomical level of herniation
   (dorsal primary ramus irritation)
2. Hypothermia along the specific thermatome
   (sinuvertebral nerve, sympathetic chain)

- **Case Study**

< Case #1>

Diagnosis: C3-4, 5-6 HIVD (40/M)

♦C/C : Pain on posterior neck
Pain on Rt. shoulder & both hand

♦Onset : 1999.1.30

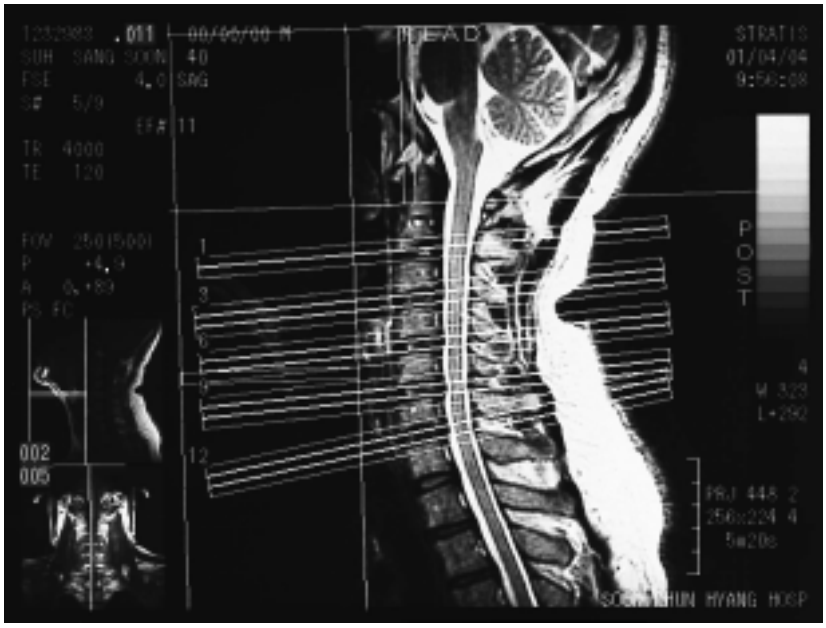
♦Duration of pain : 1 year 10 months

♦Received conservative treatment for Pass TA, often has a stiff neck when moved. Tingling and cold sensation on left posterior shoulder and left arm when rains. Swollen after sleeping.

< MRI finding>

♦C-spine MRI : HIVD at C3-4, bulging disc
HIVD at C5-6, posterocentral extrusion
Spondylosis

+++ MRI


HEAD
STRATIS
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SOON CHUN HYANG HOSP


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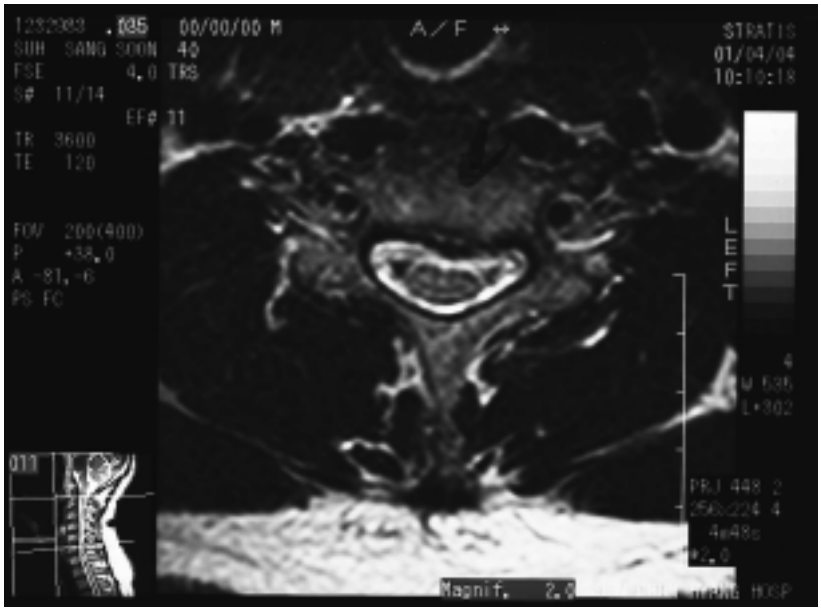
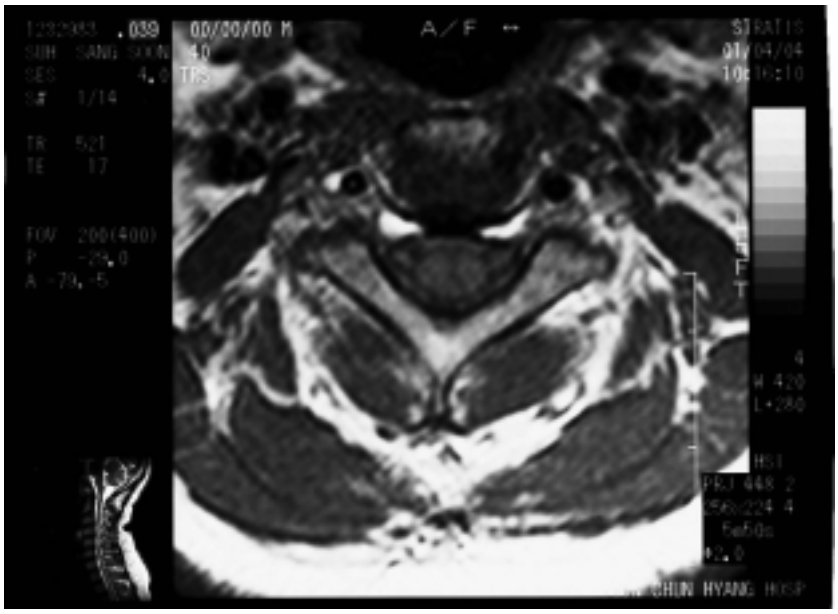
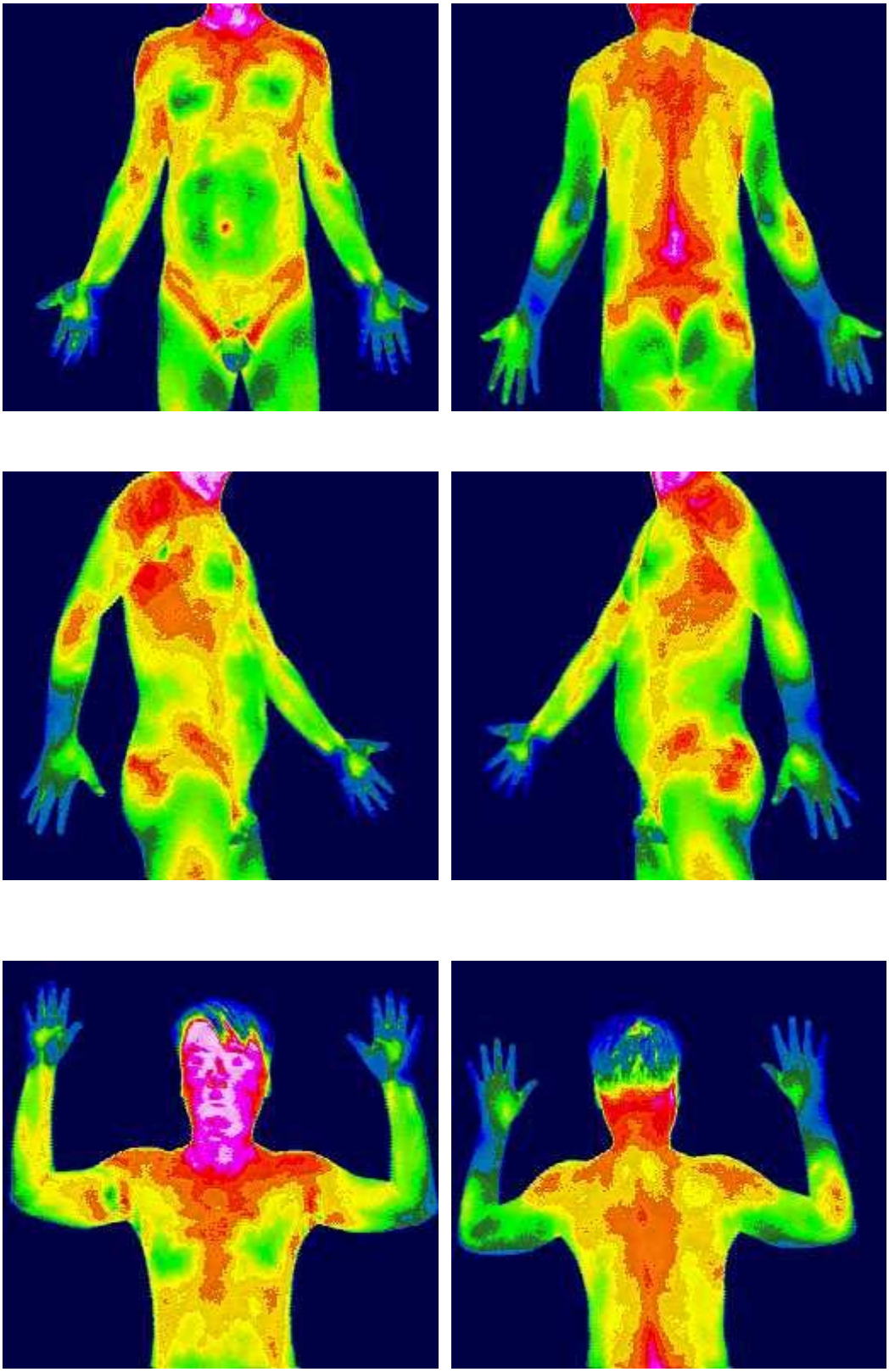
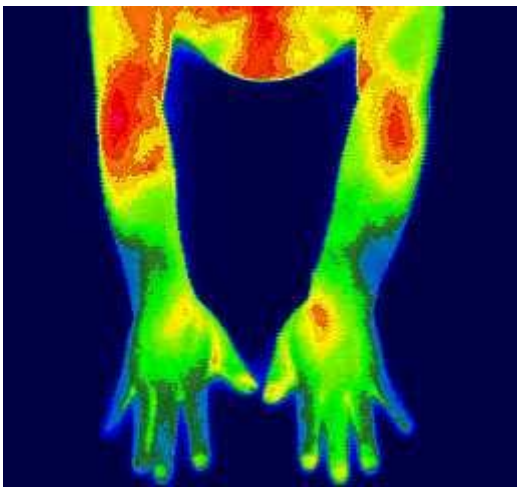
SOON CHUN HYANG HOSP

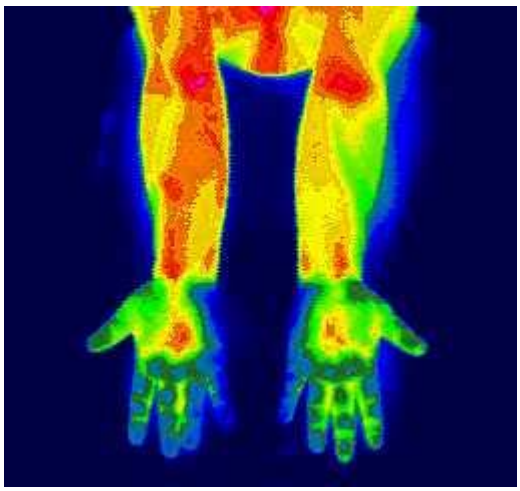

A/F
STRATIS
LEFT
Magnif. 2.0

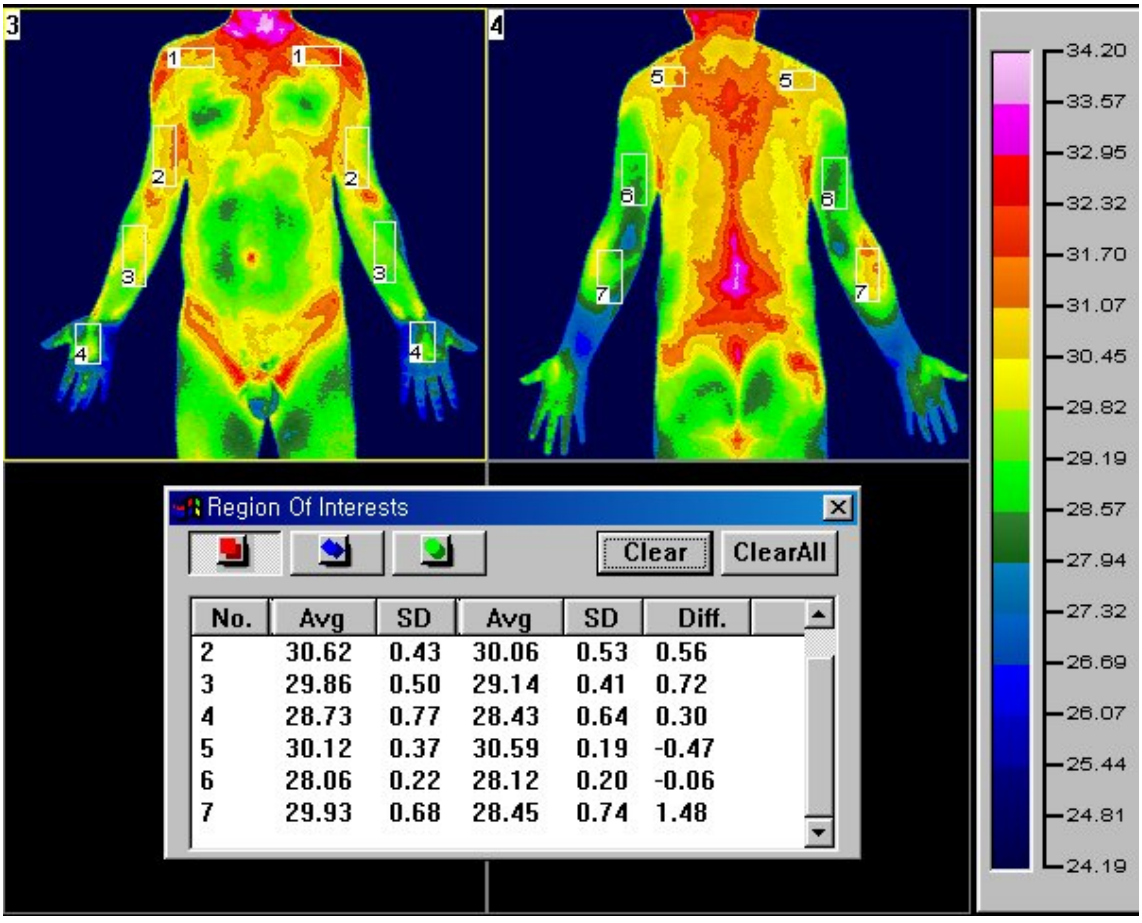

A/F
LEFT

+++ Thermogram









<Thermographic finding>

♦Loss of median heat continuity on posterior neck and upper back, and showed irregular heat flare.

♦Lt. U/E has temperature decrease on C3-4-5-6-7-8 termatome.

< Case #2>

Diagnosis: L3-4-5-S1 HIVD (F/40)

♦C/C : Pain on Lt. posterior neck & shoulder
Low back pain

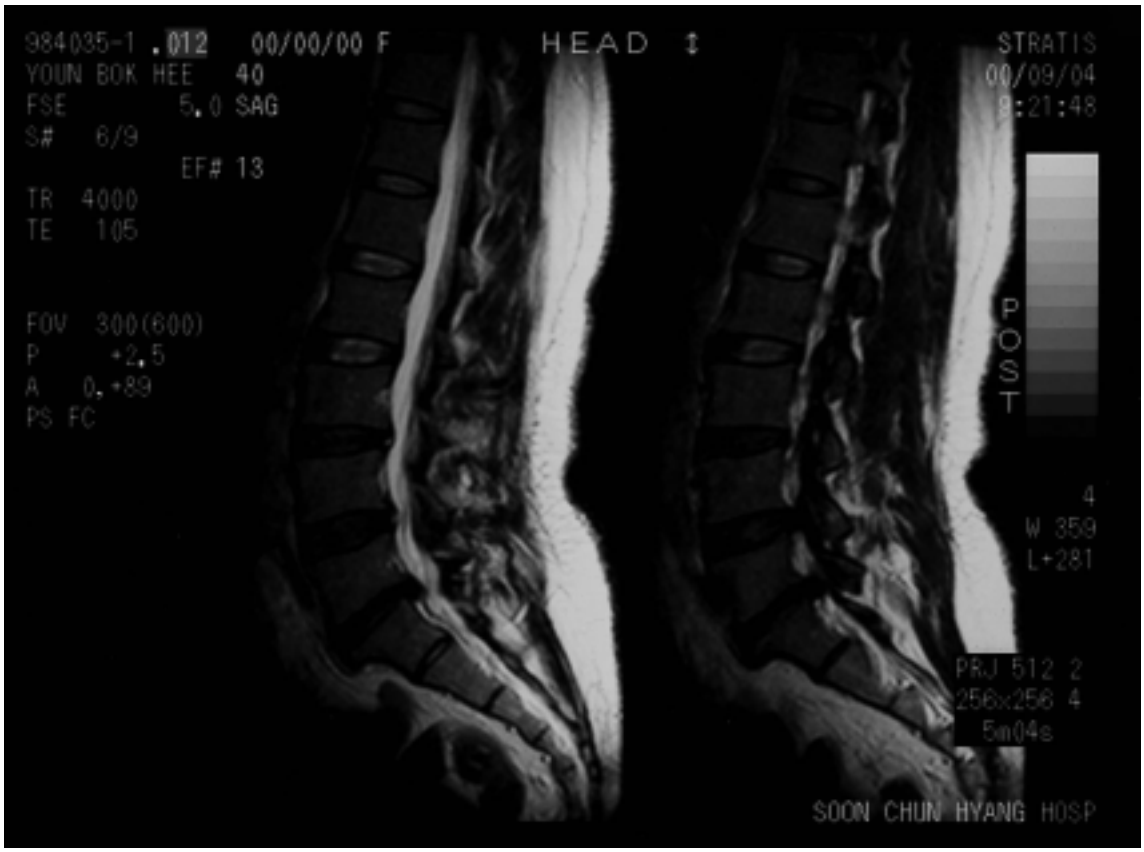
♦Onset : 2000. 1. 20

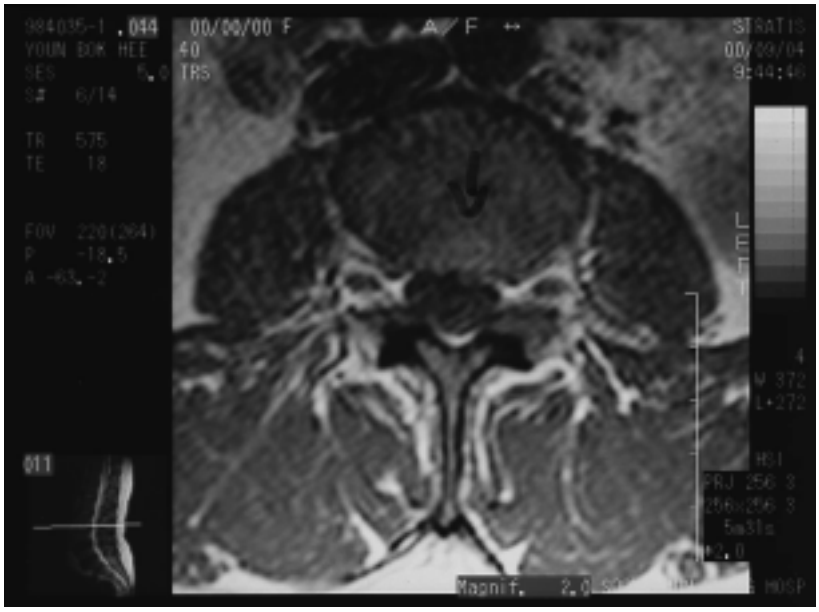
♦Duration of pain : 9 months

♦Conservative treatment due to Pass. TA. Heaviness and weakness or numbness on posterior neck via Lt.shoulder to the arm. Lt.hand was shaking when putting strength or lifting heavy objects, and the lower back was usually all right except when lifting heavy objects or working hard. On bad weathers, Lt.leg had heaviness and slight numbness. Generally, heaviness, numbness, and weakness on Lt.arm and leg.< MRI finding>

♦MRI : HIVD on L3-4-5-S1, posterocentral extrusion
Spinal stenosis

+++ MRI

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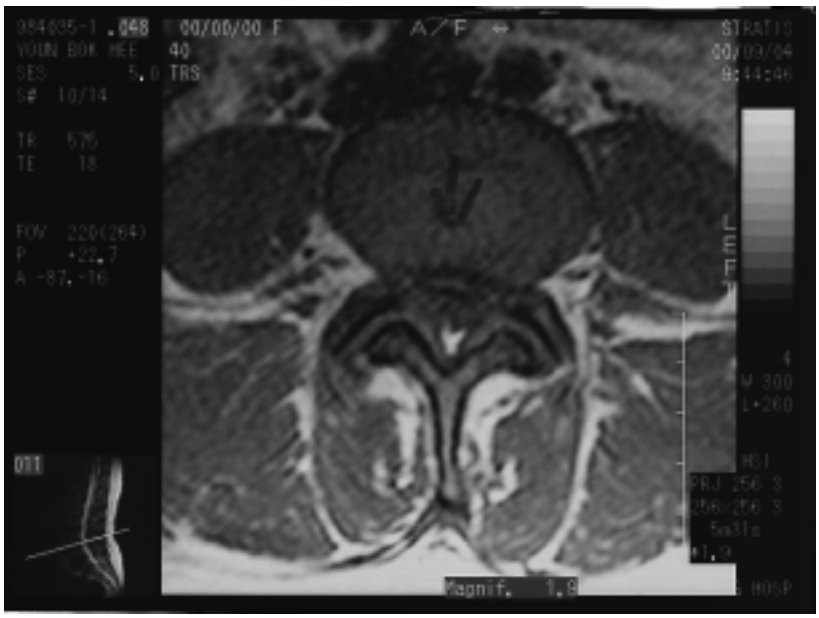
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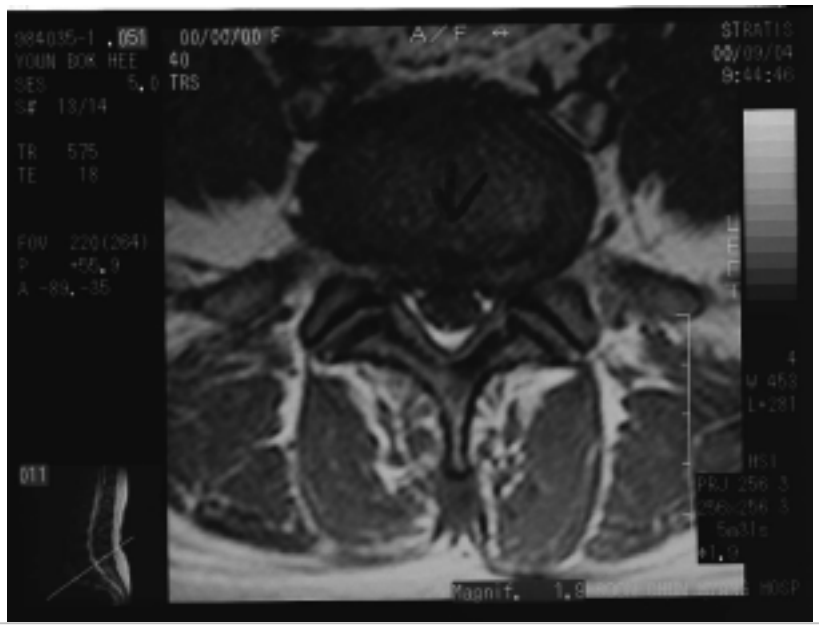
TR 575
TE 18
011
Magnif. 1.8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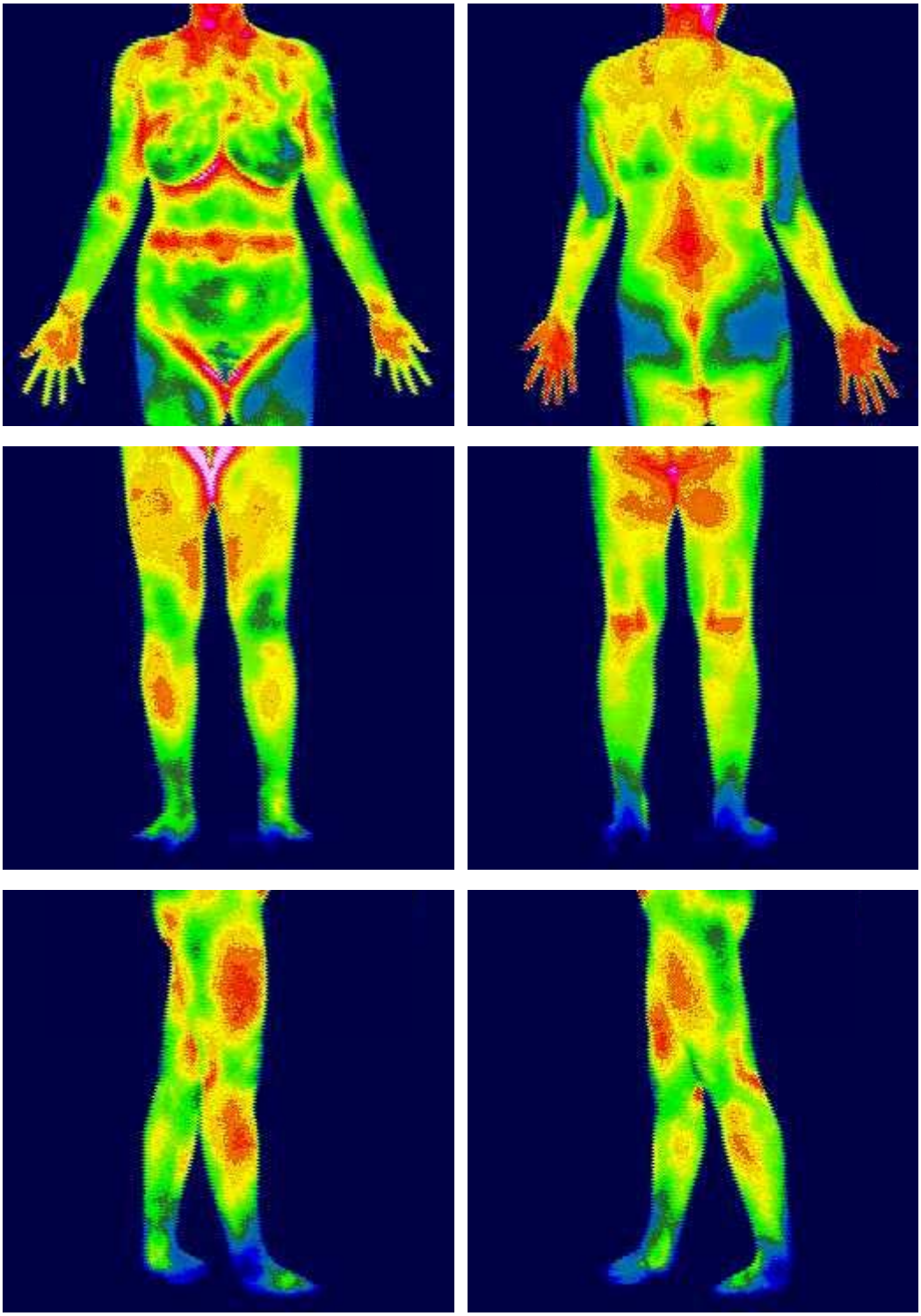
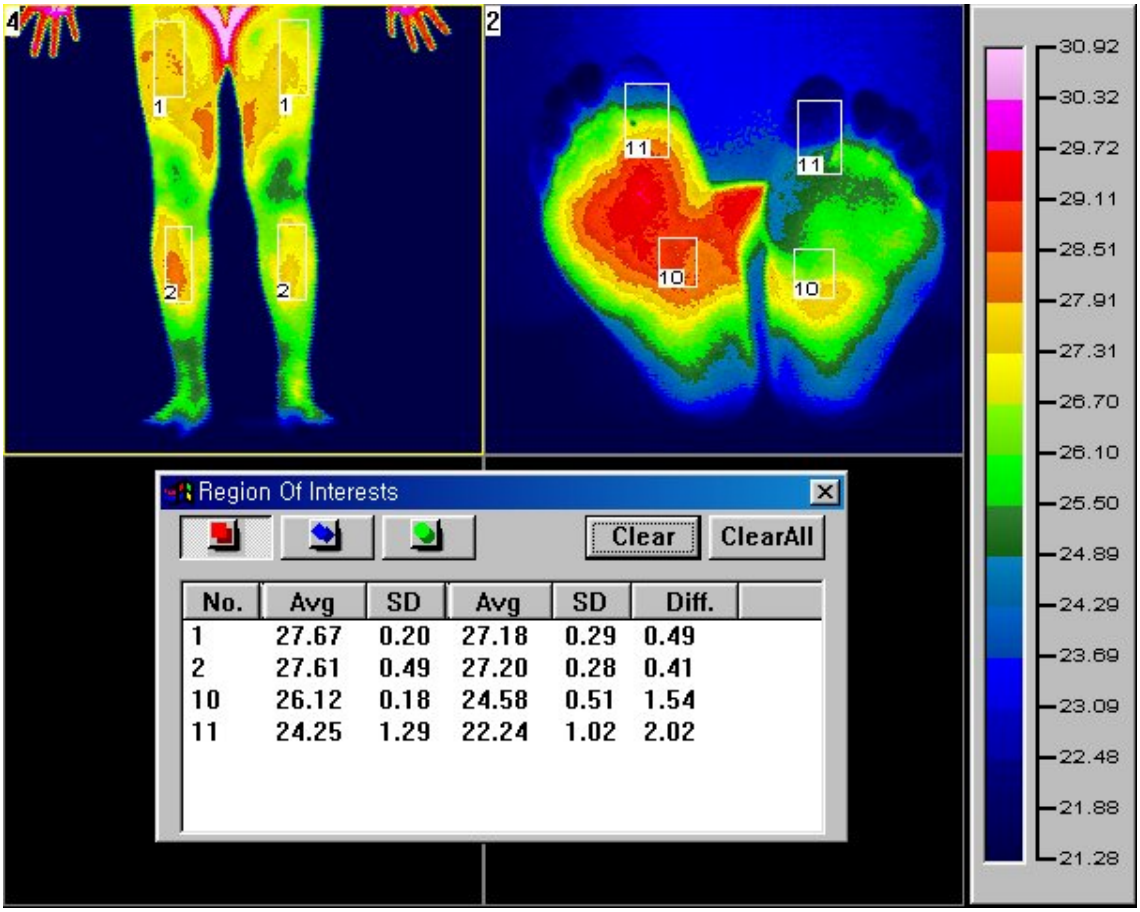
011
Magnif. 1.8

+ + + Thermogram





<Thermographic finding>

♦Loss of central heat continuity on posterior neck and upper back.

♦Asymmetric heat flare and scattering on both shoulders and scapular regions.

♦Lt.U/E had temperature decrease on C4-5-6-7-8 dermatome.

♦Loss of midline heat continuity and diamond shape on the lower back.

~~♦Lt. L/E had temperature decrease on L3-4-5-S1 dermatome.~~

5.2.1.2 Lumbar Stenosis

- Lumbar Spinal Stenosis is a narrowing of the spinal canal which compresses the nerves traveling through the lumbar spine into the legs. Although occasionally seen in younger patients (between 30 and 40) from developmental causes, it is usually a degenerative condition seen as part of the normal body aging process that develops when patients are 60 years or older.

It is not uncommon for patients to have routine x-rays as part of their initial diagnostic testing routine. They can rule out other potential problems such as fracture or tumor in the vertebrae. However, they cannot rule out spinal stenosis. A MRI or a CT scan are screening test to evaluate for its presence but with thermography more accurate diagnosis will be made.

Diagnostic Standard

1. Mild hyperthermia at the anatomical level of stenosis
   (Synovial reaction -> afferent reflex)
2. Mostly symmetrical hypothermia along nerve root dermatome
   (Subluxation , manifested by sympathetic system)

5.2.1.3 Peripheral Nerve Injury

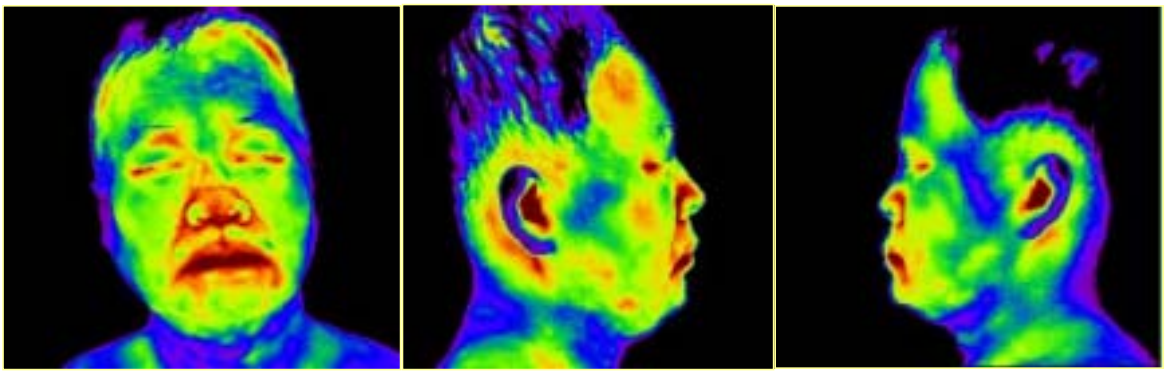
Peripheral Nerve Injury is a condition in which damage to a specific nerve(s) causes pain. Peripheral Nerve Injury may cause considerable pain in the arms or legs and may be successfully diagnosed with thermography.

The injury might be a mechanical trauma such as a knife cut, a stretch injury, a crush injury or a gunshot wound. Nerves can also be injured by compression, by infections or autoimmune diseases, and by tumors which can grow within the nerve or which can infiltrate the nerve.

Diagnostic Standard

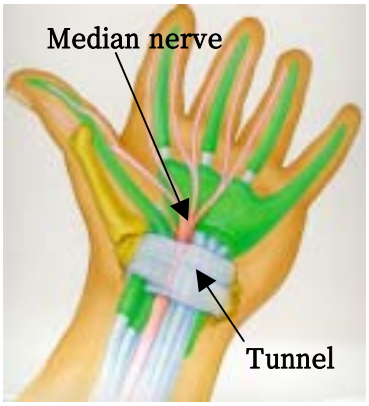
1. Hyperthermia in the distal cutaneous in acute stage
2. Hypothermia appears as the nerve regenerated

- Case Study



Peripheral Neuropathy at chronic stage : Left face hypothermia

5.2.1.4 Entrapment Neuropathy (Carpal tunnel syndrome)



The median nerve travels from the forearm into your hand through a "tunnel" in your wrist. The bottom and sides of this tunnel are formed by wrist bones and the top of the tunnel is covered by a strong band of connective tissue called a ligament. This tunnel also contains nine tendons that connect muscles to bones and bend your fingers and thumb. These tendons are covered with a lubricating membrane called synovium which may enlarge and swell under some circumstances. If the swelling is sufficient it may cause the median nerve to be pressed up against this strong ligament which may result in numbness, tingling in your hand, clumsiness or pain.

The most common cause of Carpal Tunnel Syndrome is inflammation of the tendons in the tunnel which can normally be attributed to repetitive use of the hand and/or wrist.

Diagnostic Standard

1. Chronic: hypothermia (denervation of smooth muscle in artery)
2. Acute : hyperthermia (decreased sympathetic tone)

[Suggested Diagnostic Standard for CTS (acute stage)]

=> Abnormality: more than 25% of following areas displays temperature increase more than 1℃

1. The apex of the first web space
2. The midpoint of the wirst
3. The lateral point where the hand meets the forearm
4. The lateral point at the base of the thumb

(Sheng Tchou, M.D.:Thermographic study in the acute unilateral carpal tunnel syndrome, Thermology, 1991)

Fig 15. Dorsal diagnostic area.

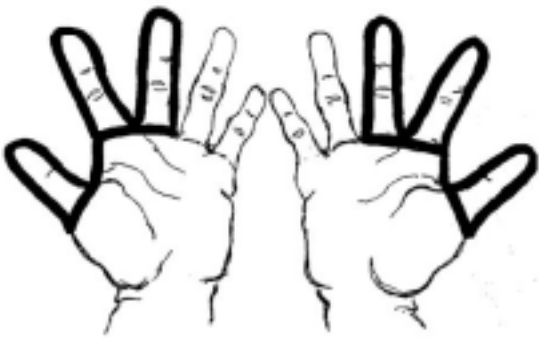


Fig 16. Palmar diagnostic area.

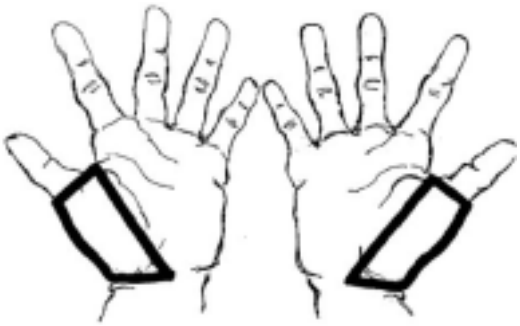
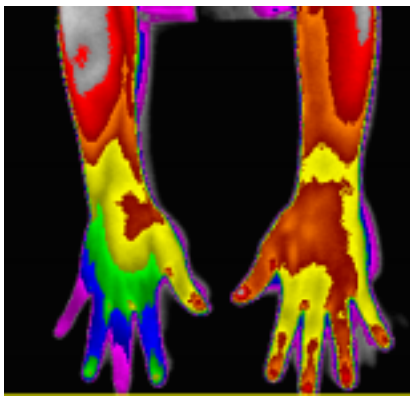
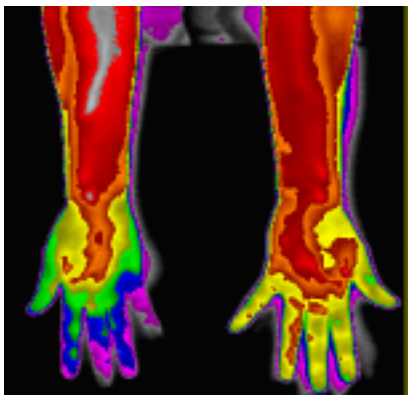


Fig 17. Thenar diagnostic area.





< Case>

Chronic stage Distinctive hypothermia on both wrist Temperature decrease on both fingers

5.2.1.5 CRPS(Complexed Regional Pain Syndrome, RSD)

Thermography can facilitate early diagnosis of CRPS, and can achieve a higher recovery rate among CRPS patients by virtue of early diagnosis of the disease. CRPS is often misdiagnosed because it remains poorly understood and there is no proper diagnostic tool except thermography. A delay in diagnosis and/or treatment for this syndrome can result in severe physical and psychological problems. Early recognition and prompt treatment provide the greatest opportunity for recovery.

CRPS, formally known as Reflex Sympathetic Dystrophy, is a chronic pain disorder involving the sympathetic nervous system. It usually is the result of an injury or trauma, but can also be a complication of surgery, infection, casting or splinting and myocardial infraction (heart attack). The trauma sets off the body's mechanism for pain recognition, but then the "normal system of pain perception" begins to misfire in it neural response, and an abnormal cycle of intractable pain begins. As RSD progresses, the abnormal pain of the sympathetic nervous system has an effect on other areas of the body and can result in total disability as muscles, bones, skin and the autonomic immune system become involved.

Some other names given to this syndrome:

1. Reflex Sympathetic Dystrophy (CRPS type I)
2. Causalgia (CRPS type II)
3. Sudeck’s Atrophy
4. Post Traumatic Dystrophy (Minor or Major)
5. Shoulder Hand Syndrome
6. Reflex Neurovascular Dystrophy

Causes of CRPS

- Trauma (often minor) such as a bruise, sprain or broken bone
- Surgery
- Myocardial Infarction (heart attack)
- Infections
- Repetitive motion disorders such as Carpal Tunnel Syndrome

Diagnostic Standard

1. Complaining severe pain but no evidence of abnormality with other diagnostic test
2. Abnormal thermal pattern with severe hyper- or hypothermia especially on the distal area.

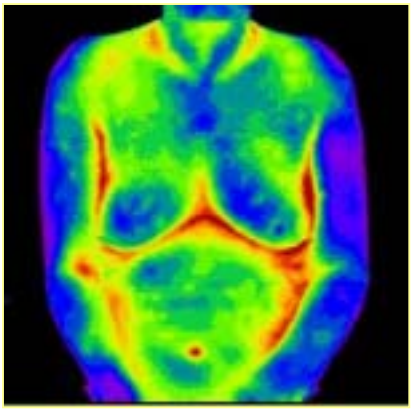
[Suggested Diagnostic Standard for CRPS]

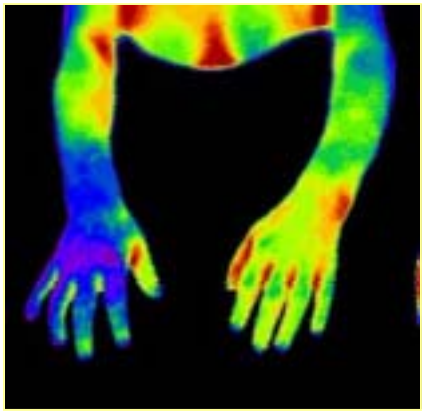
1. hyperthermia in acute stage
2. hypothermia in chronic stage

* If the hyperthermia persists and never shrinks, the prognosis is poor. (permanent damage of sympathetic nerve fibers)

(Hooshang Hooshmand: Infrared thermal imaging as a tool for pain management – an 11 year study, part II: Clinical Applications, 2001)

< Case>

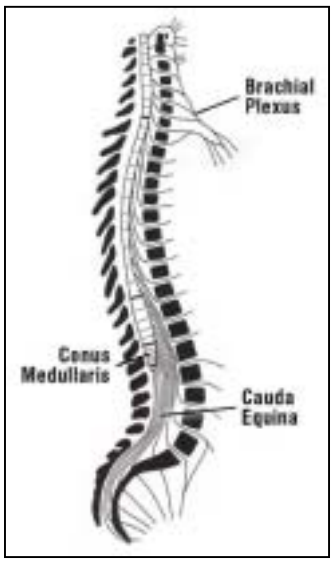




C.C: severe, unbearable pain
No anatomical change discovered with other diagnostic tests.
Overall hypothermia observed.
Hypothermia especially on distal areas (hands and fingers).

5.2.1.6 Spinal cord disorders

Thermography may be a useful first choice for estimating and identifying the location and extent of a spinal cord lesion, and it should play an important role in the follow-up of a patient.



<Spinal cord and nerve roots>

The spinal cord comes off the base of the brain, runs throughout the cervical and thoracic spine, and ends at the lower part of the thoracic spine. Therefore, spinal cord damage may accompany trauma or diseases of the cervical or thoracic spine.

Mostly patients are young people, ages 15 to 35; approximately 82% result from automobile accidents, falls, sport, and substance abuse.

Autonomic hyperreflexia resulting from stimulation occurs after two or three weeks in patients that have injuries at T7 or above. A massive reflex vasoconstriction is seen with stimulation. Compensatory vasodilation often occurs above the lesion.

Diagnostic Standard

1. Symmetrical thermal changes
   Hypothermia – under the damaged area
   Hyperthermia – above the damage area (compensation)

[Suggested Diagnostic Standard for Spinal Cord pain]

1. Thermal change at the sympathetic innervation area of the skin
2. $\Delta T > 0.3℃$ in presence of unilateral spinal cord involvment

(Takeo Ishigki, M.D.: Infrared imaging of spinal cord lesions: relation between thermal abnormalities and extent of the lesion, 1987)

<sympathetic innervation area of the skin>

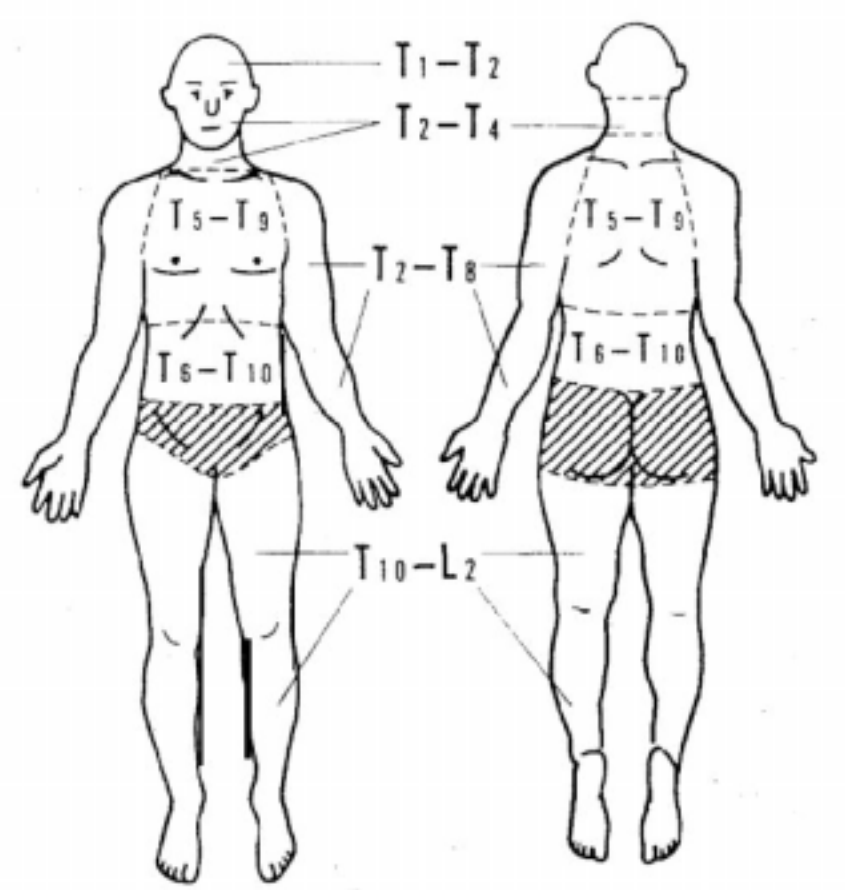


Fig 18. Sympathetic innervation of the skin. The body is divided into nine regions of sympathetic innervation, based upon spinal cord segments.

- **Case Study**

< Case #1>

Diagnosis : T-spinal cord injury (M/44)

♦C.C : Pain on both Lower leg (Rt << Lt)

♦Onset : 2000. 9. 17

♦Duration of pain : 2 months

♦Had an operation for lower body paralysis and both tibia Fx. due to the fall from the 3rd floor. Had only sensation under the knee, but not on the feet. Severe pains on the operated area and soreness and swelling with fever on the left foot.

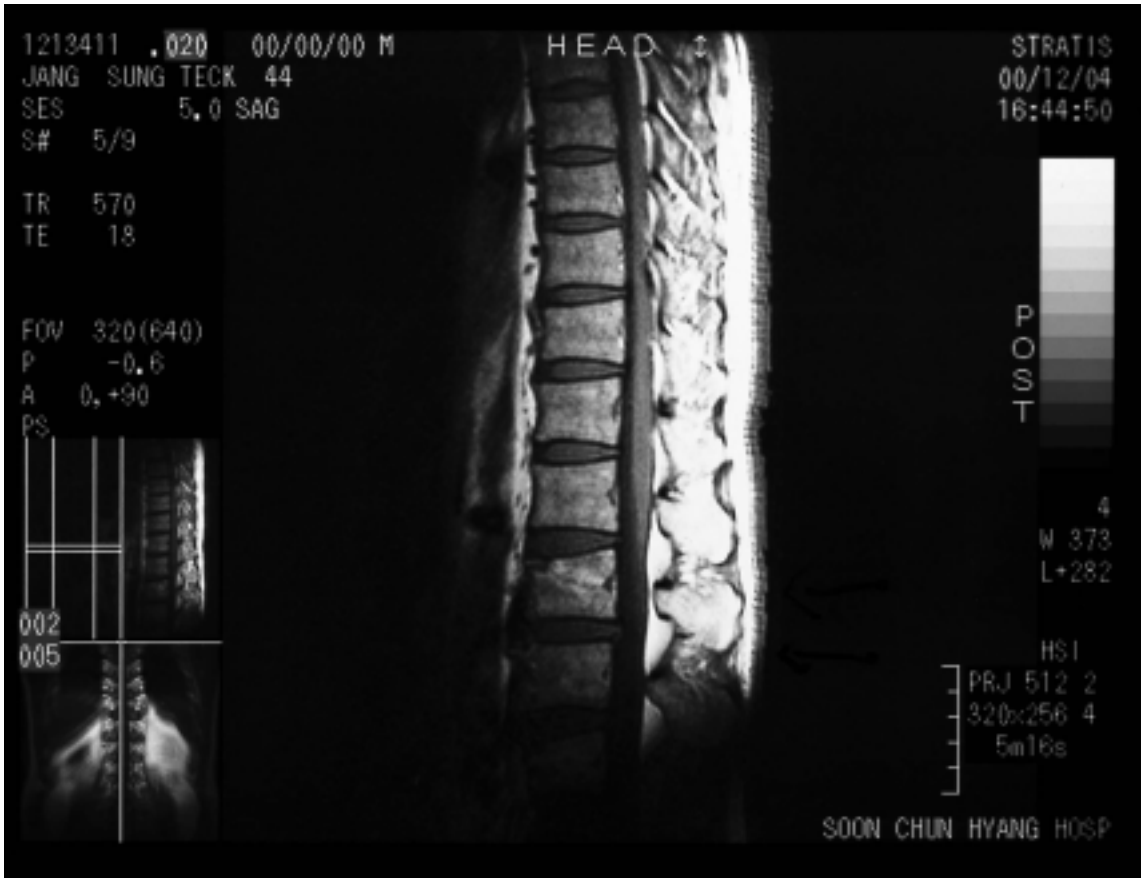
<MRI fingidng>

♦T-L junction MRI :

Traumatic spinal cord atrophy with myelomalacia in T11-L1

R/O Compression Fx. At L1-2

+++ MRI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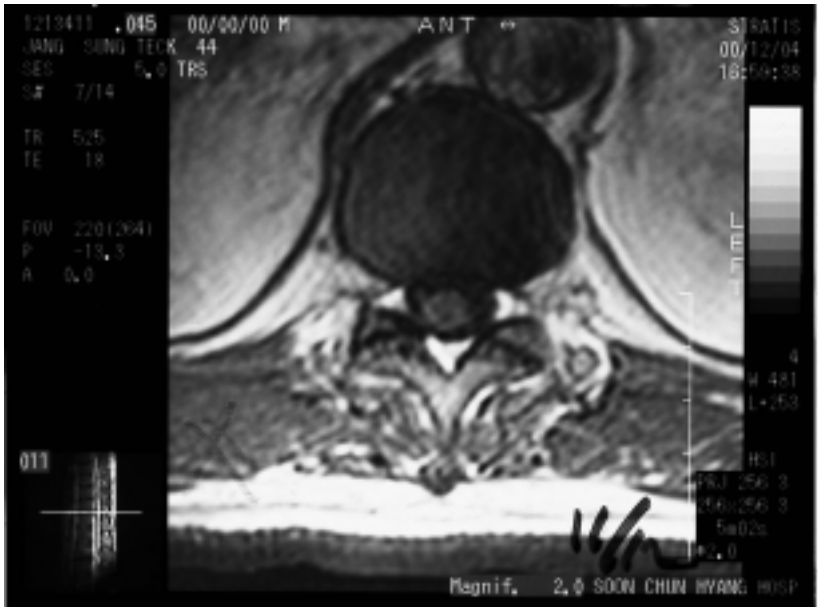
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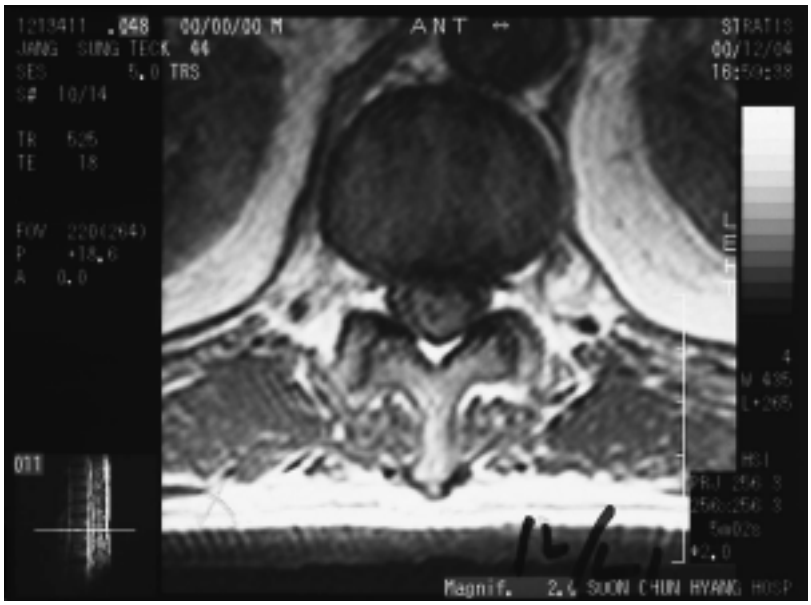
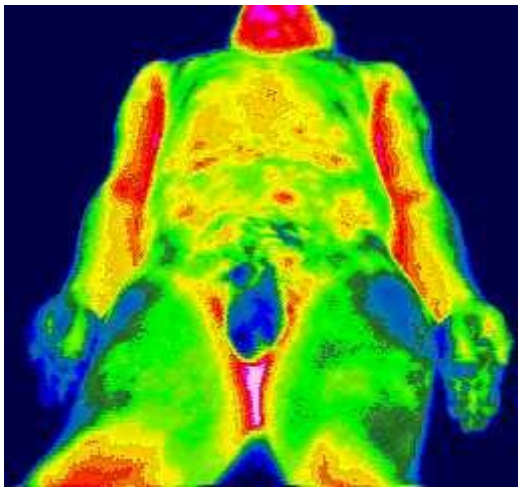
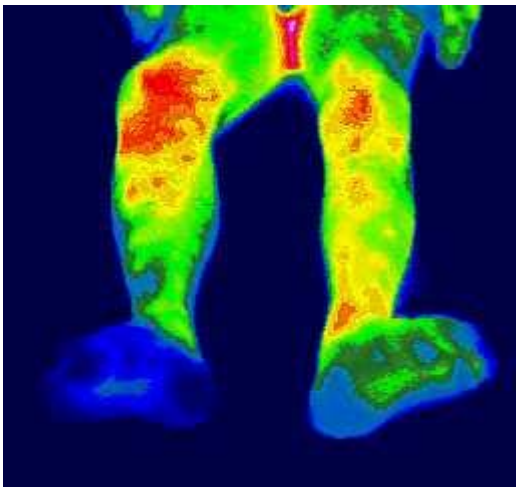
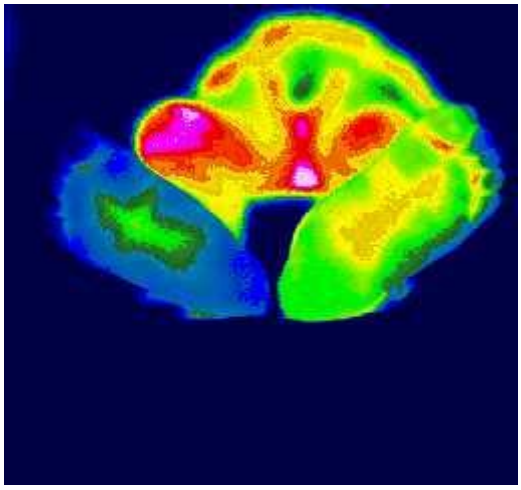


+++ Thermogram







<Thermographic finding>♦ Supine position is recommended in case of cord injury patient.

♦ Hypothermia appears under the damaged area.

♦ Lt. L/E had temperature decrease on L1-2 dermatome.

♦ Temperature increase on both knees and left ankle is due to inflammation

5.2.2 Musculoskeletal Disease

Thermography plays an adjunctive role in the diagnosis of musculoskeletal disease including structures such as the muscles, tendons, ligaments, joint capsules, joints. Sprains, strains, tears, contusions and myofascial trigger points are conditions involving these structures.

Early diagnosis is valuable because successful therapy for muscular and fascial injuries depends on prompt treatment of the acute injury. Delay in theraphy decreases the chances for complete healing and prolong recovery.

5.2.2.1 Nonradicular muscle and fascicular disorder

Diagnostic Standard for Each Disease

< Muscle spasm>
Myositis : hyperthermia
< Ligament & muscle tear or sprain>
Hyperthermia
< Myofascial pain syndrome>
Mostly hyperthermia

5.2.2.1.1 Cervical sprain

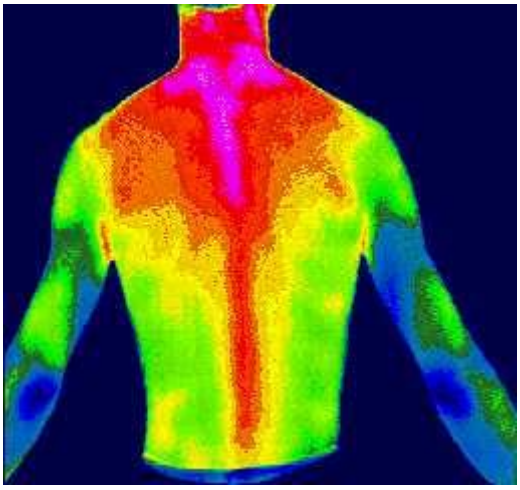
A sprain is a stretch or tear in the ligament resulting from a sudden movement that causes the neck to extend to an extreme position. For example, in the rapid deceleration of a car crash, the head and neck can stretch far forward before stopping. People who are involved in motor vehicle crashes or who take hard falls in a contact sport or around the house may get a real "pain in the neck(cervical)." This pain can result from a ligament sprain or muscle strain.

[Suggested Diagnostic Standard for Cx Sprain]

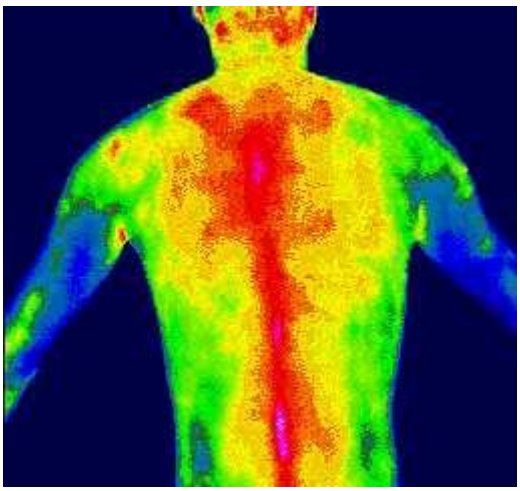
1. Abnormal thermal pattern compare with normal vascular distribution (e.g., average 0.44)
2. Cold spots (e.g., average 0.87)
3. Frequently shows both pattern (1and 2) at the same time in severe case
4. The severe the pain, the higher the frequency of hot spots and abnormal thermal pattern.

- **Case Study**

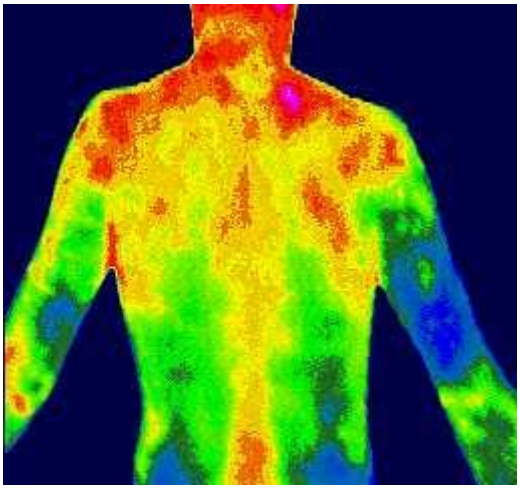
<Normal Body>



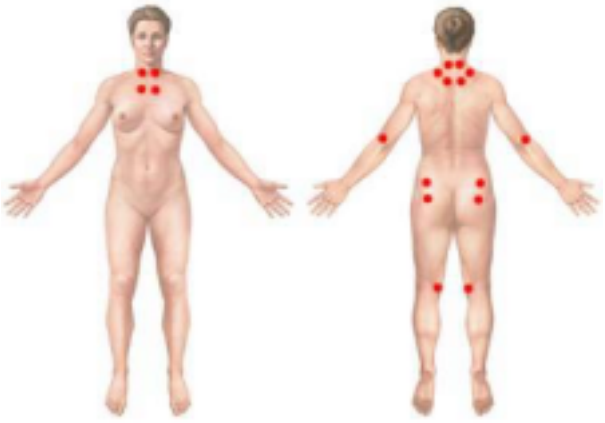
<Moderate Cx Sprain>



<Severe Cx Sprain>



5.2.2.1.2 Myofascial pain syndrome



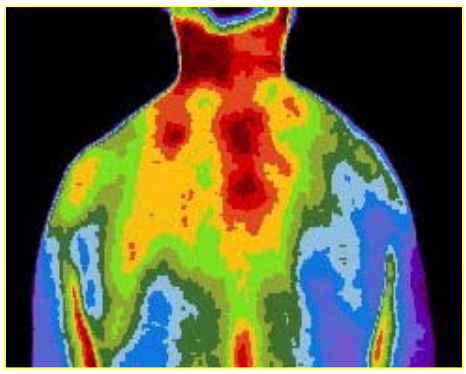
MPS or Fibromyalgia is a common condition characterized by widespread pain in joints, muscles, tendons, and other soft tissues. Some other problems commonly linked with fibromyalgia include fatigue, morning stiffness, sleep problems, headaches, numbness in hands and feet, depression, and anxiety. Fibromyalgia can develop on its own, or secondary to other musculoskeletal conditions, such as rheumatoid arthritis, or systemic lupus. Usually, small areas of extreme tenderness can be identified by pressing on the affected muscles. These spots are called "trigger points".

Diagnosis of fibromyalgia requires a history of a least three months of widespread pain, and pain and tenderness in at least 11 of 18 tender-point sites. These tender-point sites include fibrous tissue or muscles of the Neck, Shoulders, Chest Rib cage, Lower back, Thighs, Knees, Arms (elbows) and Buttocks.

[Suggested Diagnostic Standard for MPS]

1. Distinguished hot spot (trigger point)
2. Characteristics of the trigger point : Thermal difference (ΔT) > 1.0℃
   5-10mm diameter
   Disc shape

(AMA Council Report: thermography in neurological and musculoskeletal conditions, 1987)



- Case Study

Pain on the neck and shoulder area Three disc shape hot spots Thermal difference greater than 1.0℃ (1.8℃)

5.2.3 Inflammatory Disease

Heat is associated with many conditions and inflammation is major one of those conditions. Inflammatory disease will be detected and identified by thermography and will be diagnosed accurately using thermography with MRI and CT which provide anatomical information of body.

Thermography has its role especially in detection of disease without realized symptom, so makes early treatment possible, evaluation of medication efficacy and decision of disease stage.

5.2.3.1 Osteoarthritis

Arthritis is one of the most common medical problems in the world. The word *arthritis* is a blend of the Greek words *arthron,* for joint, and *itis,* for inflammation. In other words, *arthritis* literally means "joint inflammation." Although arthritis is often referred to as one disease, it's not. There are more than 100 forms of arthritis.

Osteoarthritis, sometimes called degenerative arthritis, degenerative joint disease or osteoarthrosis, is the most common form of arthritis. It is most common in women and adults over age 45. It may affect any joint in your body, including those found in the fingers, hips, knees, lower back and feet. Initially it tends to strike only one joint.

Diagnostic Standard

1. Disappearance of the normal thermal contour line on the knee
2. Hot area or spot on inflamed area
3. Overall hyperthermia around the painful joint area

* Cold area appears in case of severe and chronic arthritis

- **Case Study**

<Case #1>

♦Patient info.: F/47

♦C.C: Moderate pain on right knee

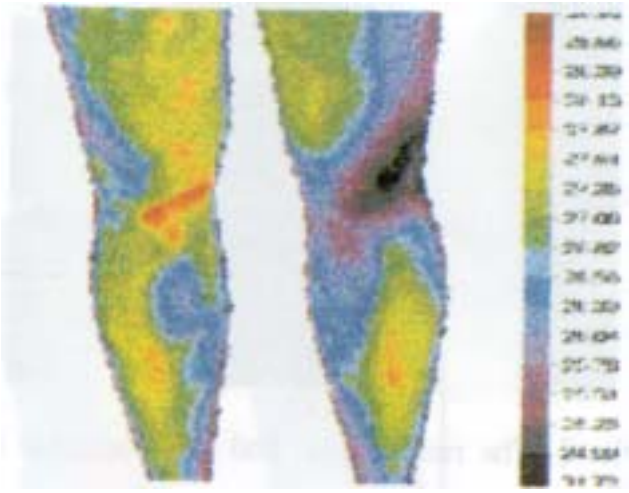
♦Duration: 3 years

♦VAS test : Left 20, Right 80

♦Physical exam: swelling , heating , crepitus at right knee joint

♦**CT: No abnormality observed**

♦**Thermography: Hot line observed on the right knee**



<Case #2>

♦Patient info.: M/64

♦C.C: Moderate pain on left knee

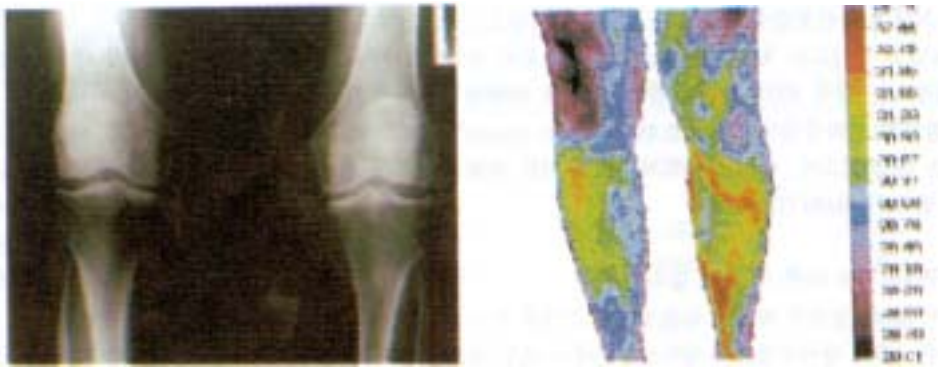
♦Duration: 4 years

♦VAS test : Left 80, Right 40

♦Physical exam: crepitus at both knee and swelling suspected at left knee joint

♦**CT: Mild joint gap reduction observed**

♦**Thermography: General hyperthermia with distinctive hot spot on left knee area**



<Case #3>

♦Patient info.: F/85

♦C.C: severe pain on both knee

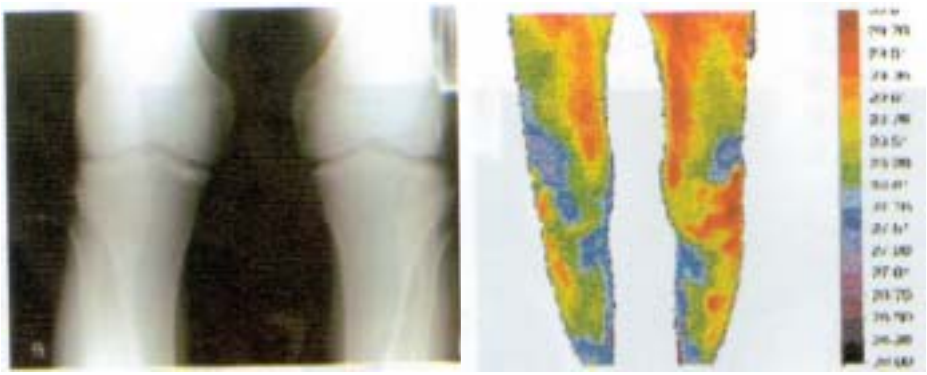
♦Duration: 10 years

♦VAS test : Left 100, Right 100

♦Physical exam: severe swelling , crepitus at both knee joint

♦**CT: Joint gap reduction at both knee, induration of the bone under cartilage, irregularity of the joint surface observed**

♦**Thermography: General hyperthermia with distinctive hot spot on left knee area**



5.2.4 Vascular Disease

The core temperature of our body conducts to the skin by blood circulation so, blood circulation can induce the change of skin temperature. It is reported that each peripheral vessel makes different thermal pattern. This will be a good indicator for diagnosis of vascular disorders as thermography visualizes these thermal patterns distinctively. Thermography also has great value for the treatment evaluation of vascular disorders.

5.2.4.1 Raynaud's Disease


Raynaud's Phenomenon

Raynaud's phenomenon (RP) is a condition resulting in discoloration of the fingers and/or the toes when the patient is exposed to changes in temperature (cold or hot) or emotional events. Skin discoloration occurs because an abnormal spasm of the blood vessels results in a diminished blood supply. Initially, the digit(s) involved turn white because of diminished blood supply. The digit(s) then turn blue because of prolonged lack of oxygen. Finally, the blood vessels reopen, causing a local "flushing" phenomenon, which turns the digit(s) red. This three-phase color sequence (white to blue to red), most often upon exposure to cold temperature, is characteristic of RP. Raynaud's phenomenon most frequently affects women, especially in the second, third or fourth decades of life. Persons can have Raynaud's phenomenon alone or as a part of other rheumatic diseases.

[Suggested Diagnostic Standard]

1. Finger Lesion
2. Confusion pattern of lower temperature & normal in 5 fingers
3. Slight change of toes and lower limbs
4. Arthritis
5. Coldness induce low temperature pattern
6. Delayed recovery from coldness

[Diagnosis with thermal stress test]

Mild stress at 20 in an ambient temperature of 24

- Normal thermal recovery

1. Recovery to mean prestress temperature levels in normal subjects takes place much faster than in vasospastic subjects (e.g. 4-12 minutes: as opposed to 15-60 minutes.)

2. The major of healthy control subjects exhibit the following sequence of events.

Palmar Surface

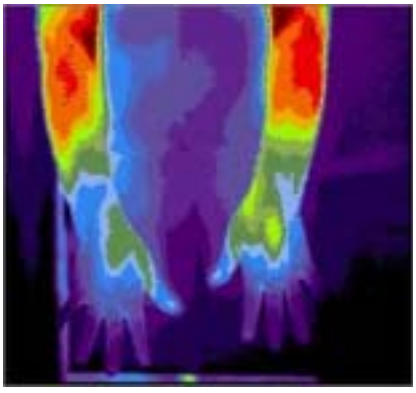
a. Initial warming of the palm to the base of the fingers.
b. Digital flow to the fingertips followed by opening of the anastomoses, causing rapid warming of the fingertips.
c. Subsequent warming from the fingertips proximally, and from the base of the fingers distally

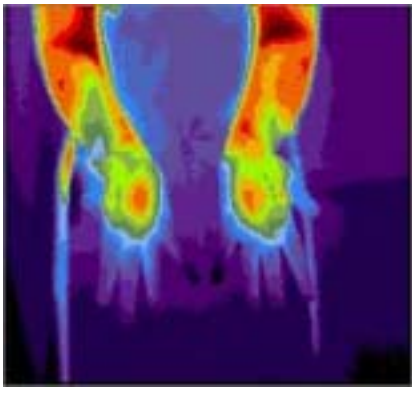
Dorsal Surface

a. Initial heating of the nailed area
b. Superficial veins on the dorsum of the hand are shown to be conducting cold blood
c. Digital veins become warm proximally, followed by the veins on the dorsum of the hand, leaving the area over the metacarpophalangeal joints cold

(E.F.J Ring: Raynaud's Phenomenon: Assessment by Thermography, Thermology, 1988)

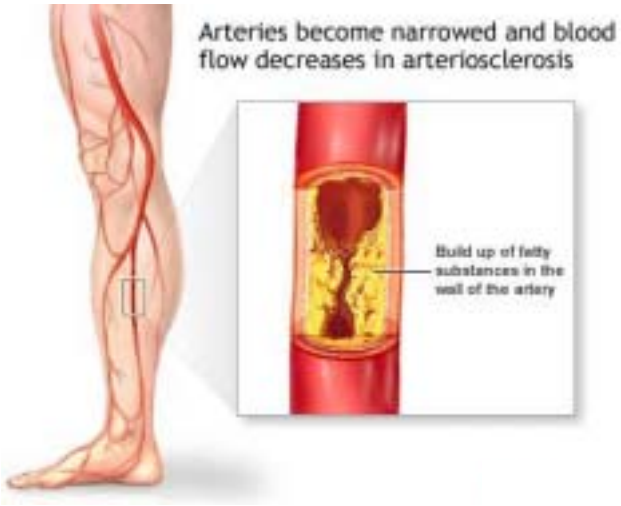
- Case Study





Coldness induce low temperature pattern Overall hypothermia on the hand

5.2.4.2 ASO (Arteriosclerosis Obliterance)



ASO is a disease of the peripheral blood vessels that is characterized by narrowing and hardening of the arteries that supply the legs and feet. A decrease in blood flow results.

Arteriosclerosis, "hardening of the arteries" commonly shows its effects first in the legs and feet. The narrowing of the arteries may progress to total closure (occlusion) of the vessel. The vessel walls become less elastic and cannot dilate to allow greater blood flow when needed (such as during exercise). Calcium deposits in the walls of the arteries contribute to the narrowing and stiffness.

It is a common disorder usually affecting men over 50 years old. Twenty percent of people over age 64 will suffer from arteriosclerosis of the extremities.

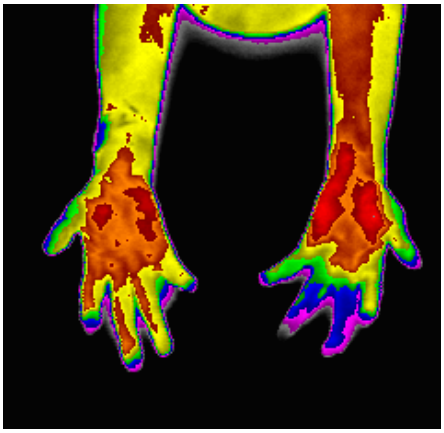
Persons are at higher risk if they have a personal or family history of coronary artery or cerebrovascular disease, diabetes, smoking, hypertension, or kidney disease involving hemodialysis.

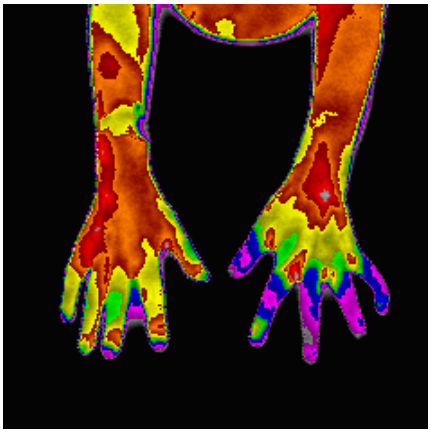
[Suggested Diagnostic Standard]

1. Lower limb lesion
2. Lower temperature than normal case or site
3. Wide low temperature pattern
4. Rare change of temperature distribution pattern
5. High temperature pattern could be appeared around the obstructed lesion
6. Same temperature decrease pattern under the obstructed lesion
7. Rare hand lesion

(Kyung-Sub Lee: Cinical Application of DITI induced by Blood Stasis, 2002)

- Case Study





ASO on the hand (especially left hand)
Hyperthermia around the obstructed lesion
Hypothermia under the obstructed lesion (finger area)

5.2.4.3 TAO (Thromboangiitis Obliterance, Buerger's disease)

TAO is a disorder that leads to obstruction of the blood vessels of the hands and feet.

Vasculitis (an aggressive form of inflammation) targets the lining of the small arteries and veins, causing thromboangiitis obliterans (Buerger's disease). The blood vessels of the hands and feet become constricted or totally obstructed because of the inflammation and clots. This reduces the availability of blood to the tissues, causing pain and eventually damaging or destroying the tissues, and making them more prone to infections and gangrene.

Thromboangiitis obliterans affects approximately 6 out of 10,000 people. It almost always affects men, 20 to 40 years old, who have a history of smoking or chewing tobacco. This may also be associated with a history of Raynaud's disease. This disorder is very uncommon in children, but it may occur in those with autoimmune diseases.

[Suggested Diagnostic Standard]

1. Both legs lesion
2. Lower temperature pattern of some toes
3. Many finger lesions
4. Mixed loading of low and high temperature pattern
5. Phlebitis induced high temperature pattern
6. Confusion of temperature pattern

(Kyung-Sub Lee: Cinical Application of DITI induced by Blood Stasis, 2002)

6. Treatment Evaluation

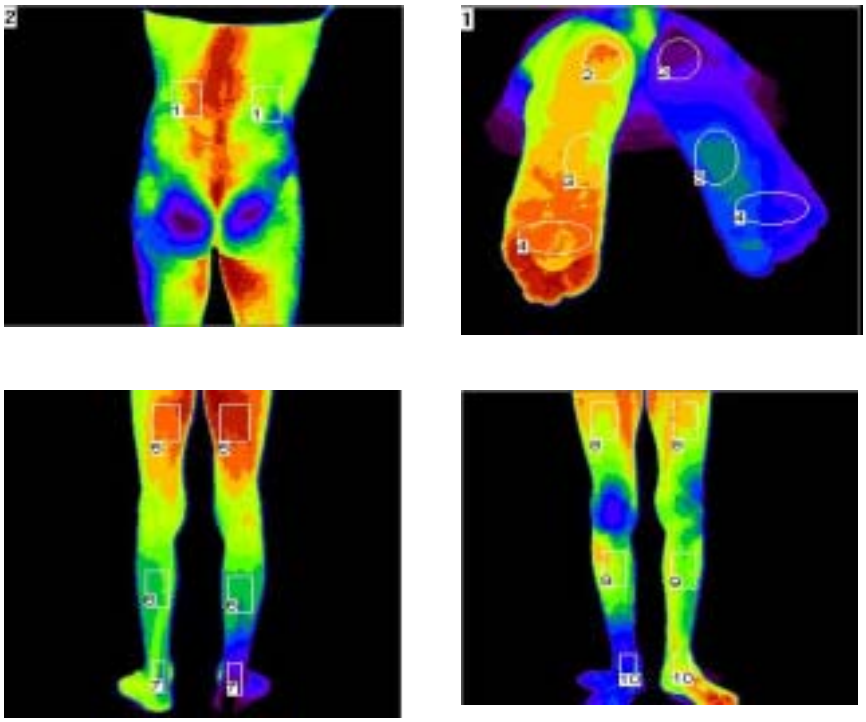
Treatment progress can be evaluated by comparing thermal images of pre- and post-treatment as blood circulation recovery is a strong indicator of physiological improvement. Further interventions have to be discussed when the image of post treatment is not showing significant thermal improvement.

6.1 DRG block (Dorsal Root Ganglion block)

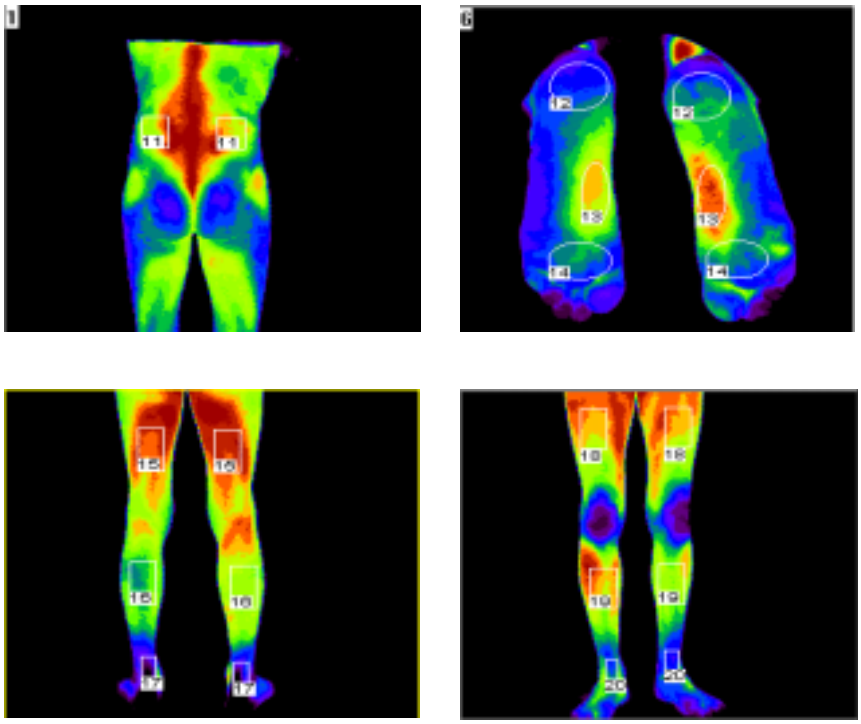
: Shows significant thermal change (symmetry) after treatment

Choi 0 0 (M/58): FBSS, severe Rt L5/S1 radiculopathy
RF DRG block: VAS 9 -> 3

Pre-



Post-



	Pre-	Diff.	Post-
1	-0.75	0.80	0.05
2	-6.27	6.78	0.51
3	-3.27	3.80	0.53
4	-5.02	5.15	0.13
5	0.61	0.33	0.28
6	-0.34	1.14	0.80
7	-4.22	4.38	0.16
8	-0.11	0.10	-0.01
9	0.62	0.18	0.80
10	-4.18	4.95	0.77

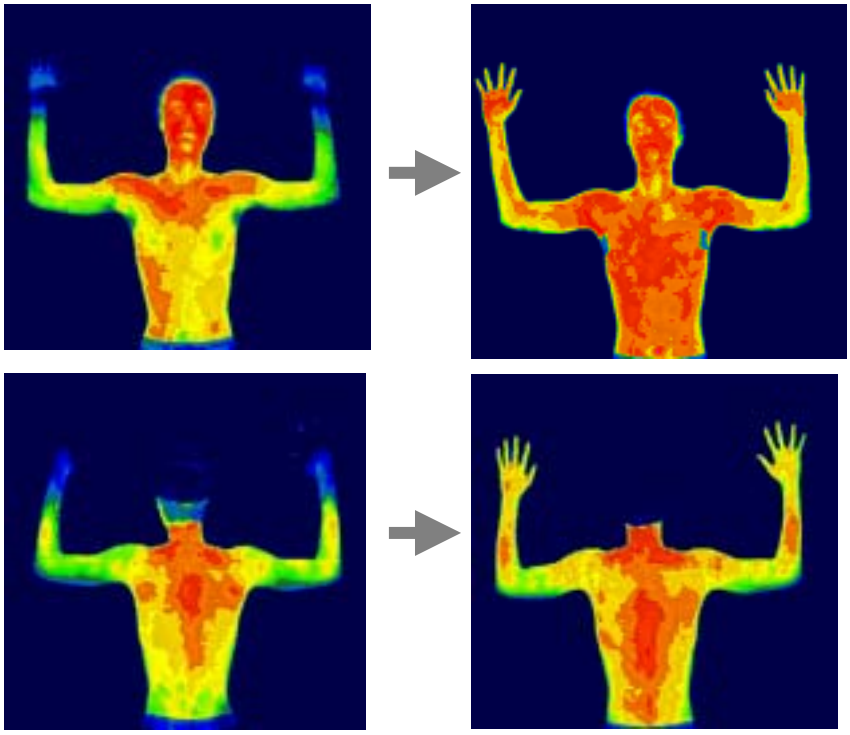
	Pre-		Diff.	Post-		Diff.
1	32.93	33.68	-0.75	34.72	34.67	0.05
2	24.21	30.48	-6.27	27.49	26.98	0.51
3	26.96	30.23	-3.27	29.73	29.20	0.53
4	25.89	30.91	-5.02	27.55	27.42	0.13
5	33.74	33.13	0.61	33.97	33.69	0.28
6	29.56	29.90	-0.34	32.34	31.54	0.80
7	25.54	29.76	-4.22	28.62	28.46	0.16
8	32.06	32.17	-0.11	33.13	33.14	-0.01
9	31.28	30.66	0.62	33.14	32.34	0.80
10	27.73	31.91	-4.18	31.27	30.50	0.77

2) Sympathectomy (Hyperhidrosis cases)

< Case #1> M/28

Pre-

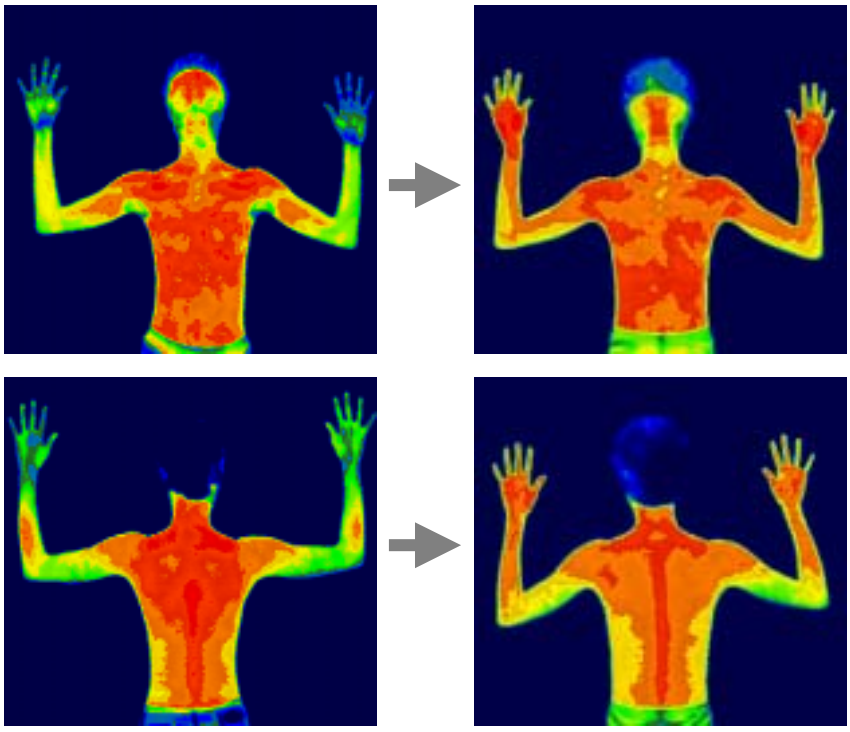
Post-



< Case #2> M/23

Pre-

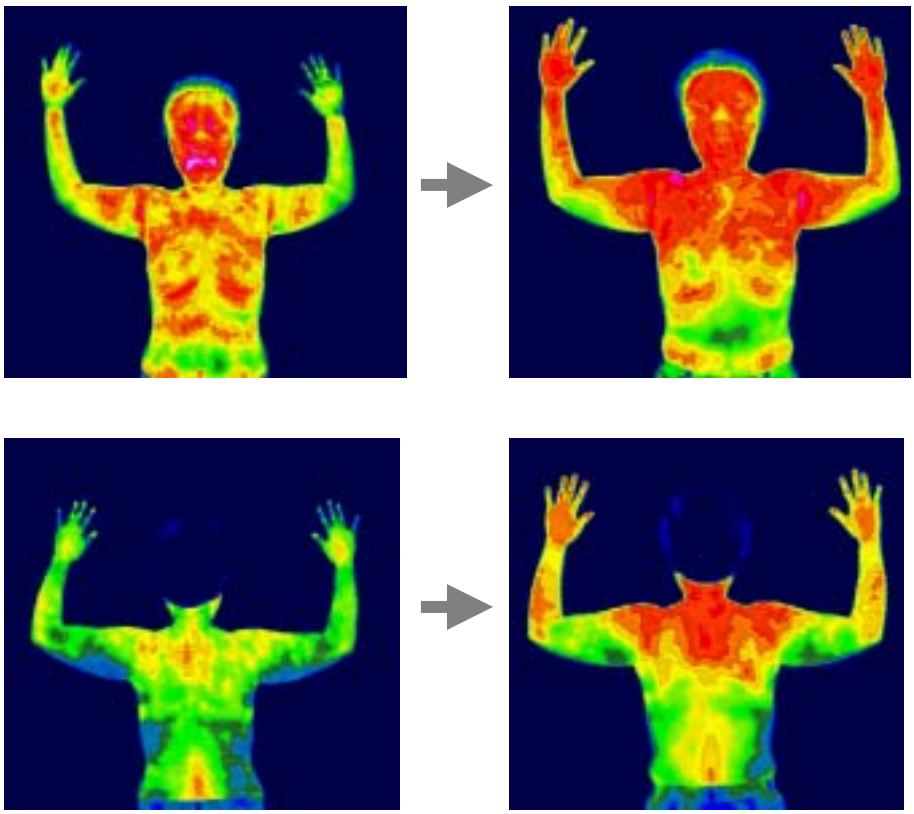
Post-



< Case #3> F/42

Pre-

Post-

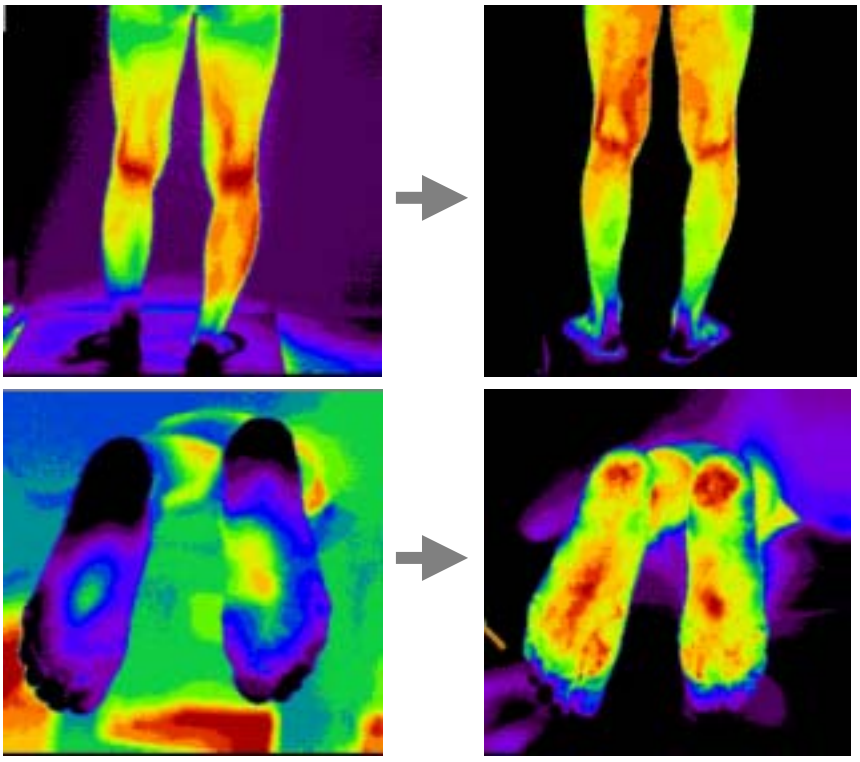


3) Laminectomy (HIVD case)

< Case #1> M/32

Pre-

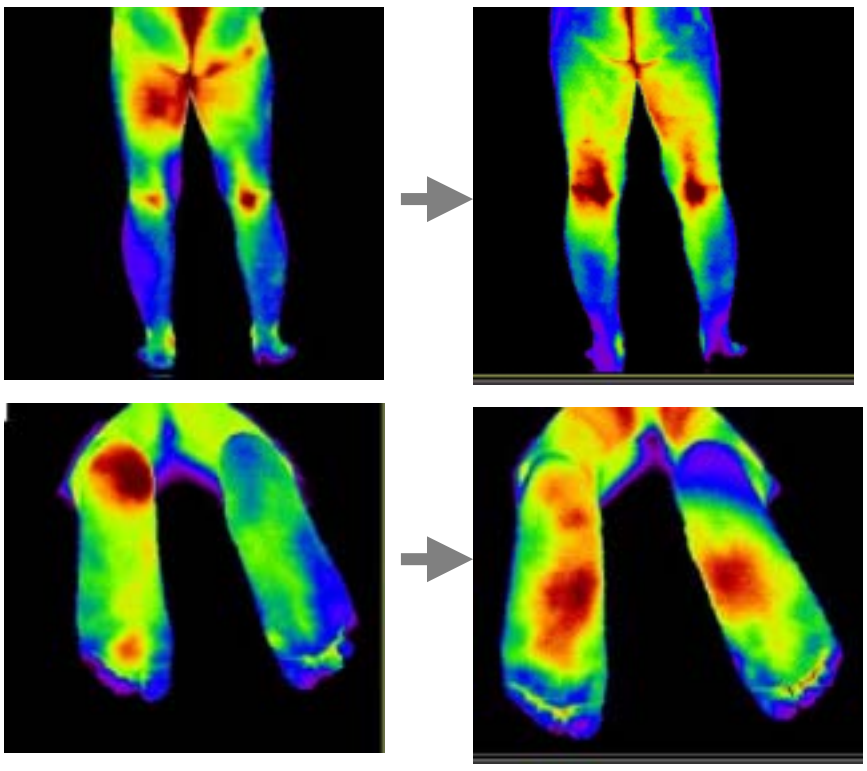
Post-



< Case #2> M/39

Pre-

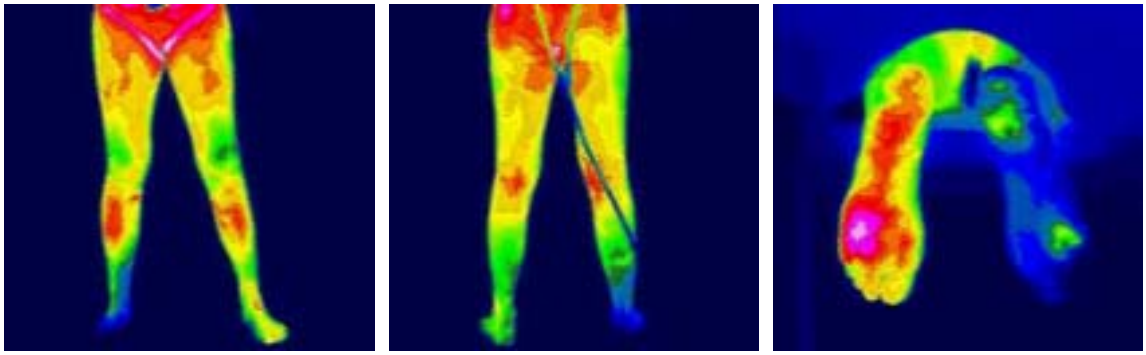
Post-



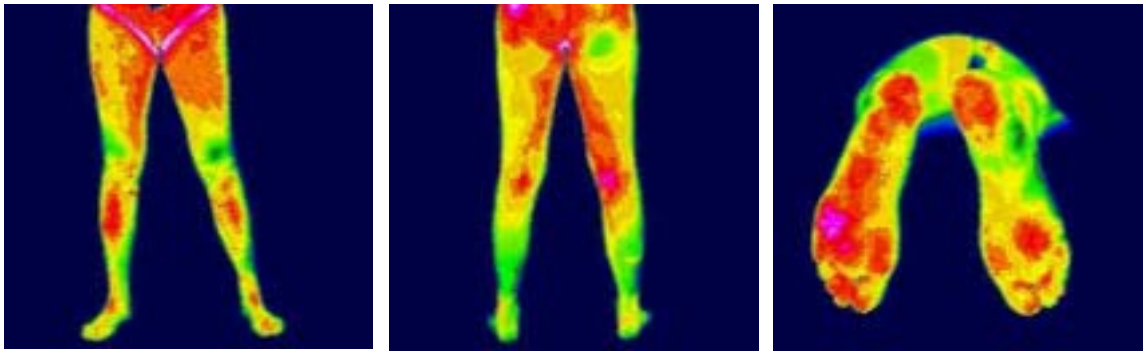
4) IMS (Intra Muscular Stimulation: HIVD case)

< Case> F/30

Pre-

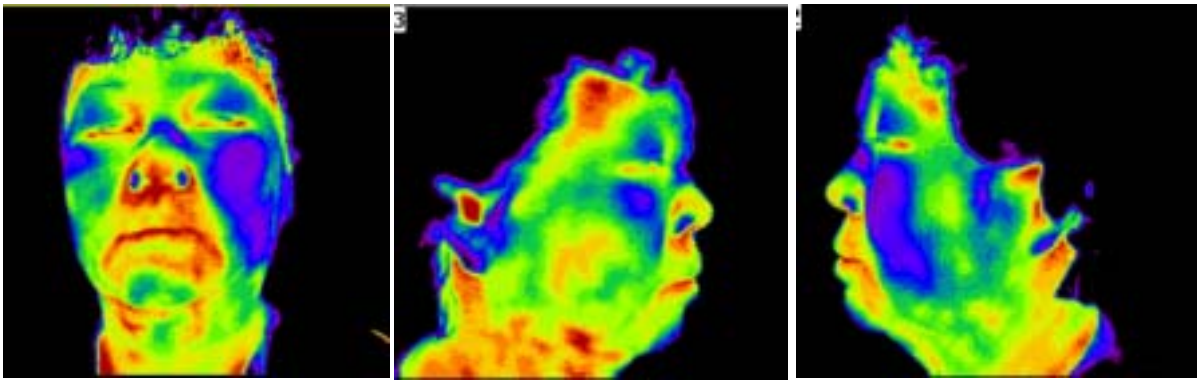


Post-

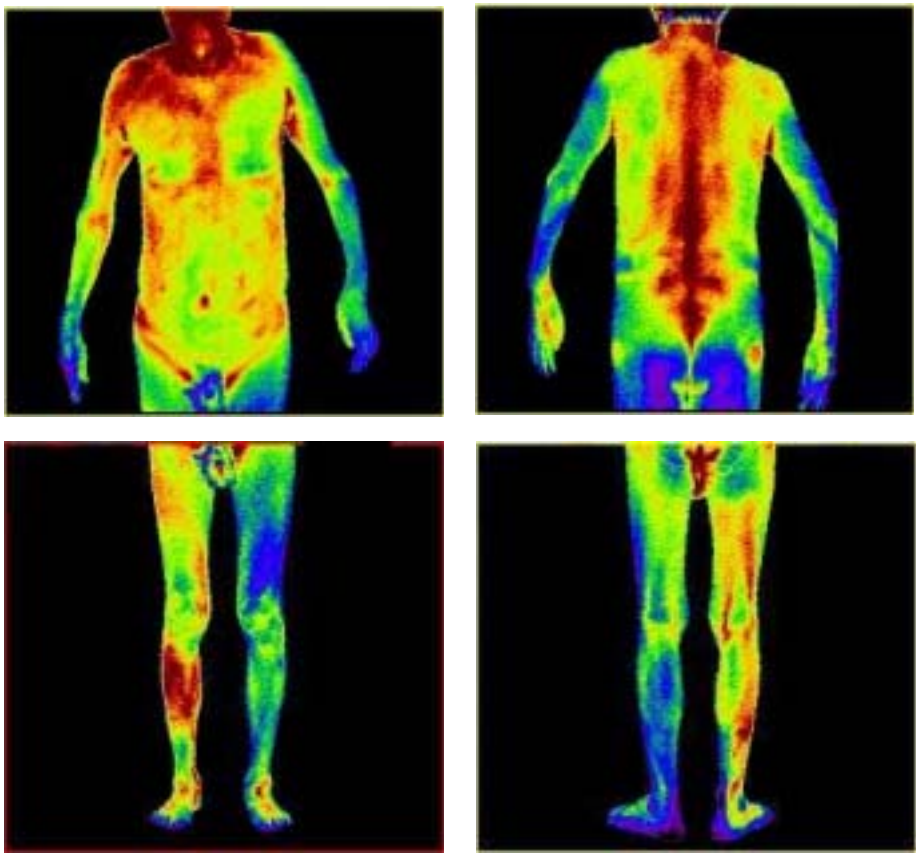


7. Image Collection

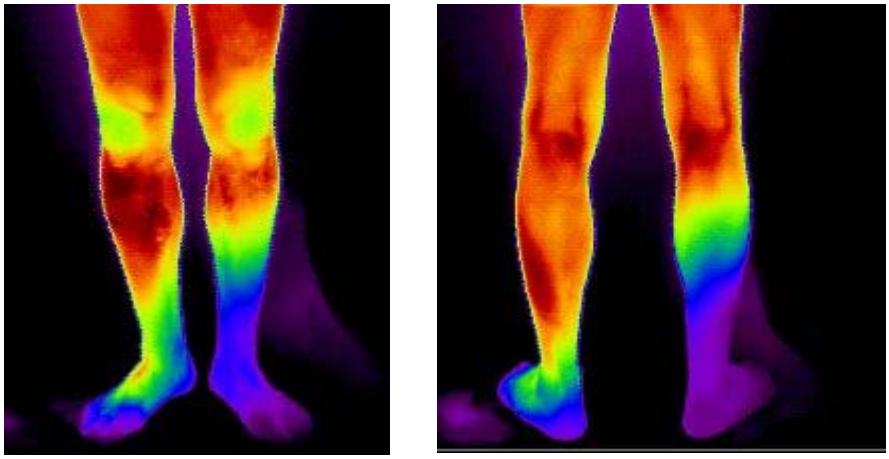
7.1 Facial (Bell's) Palsy



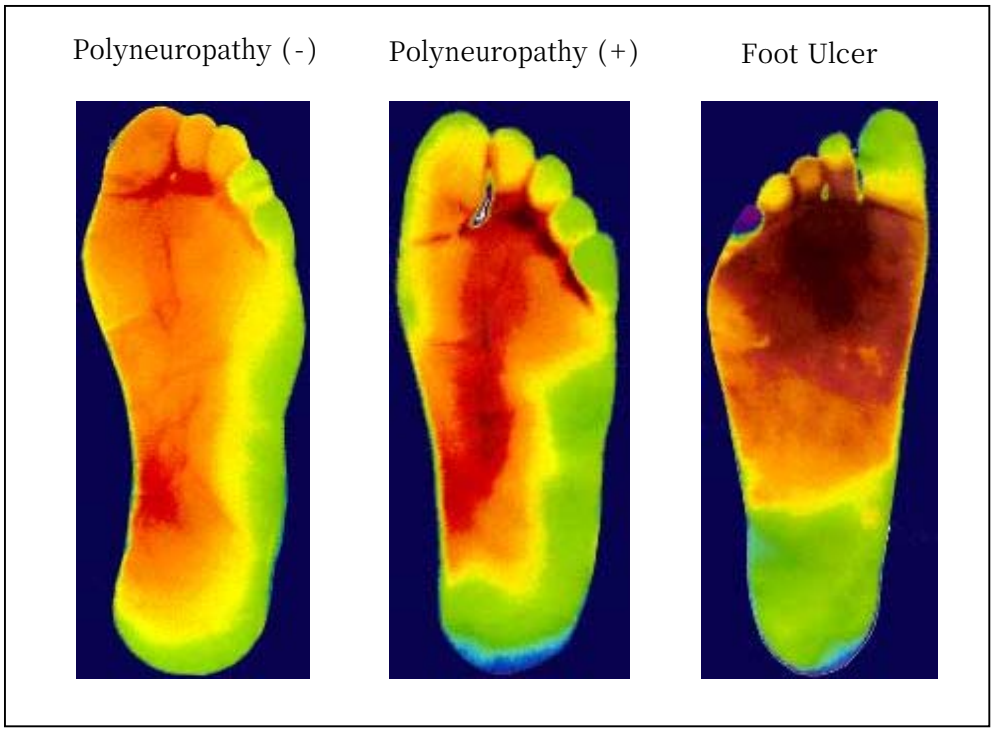
7.2 CVA (Cerebral Vascular Accident)



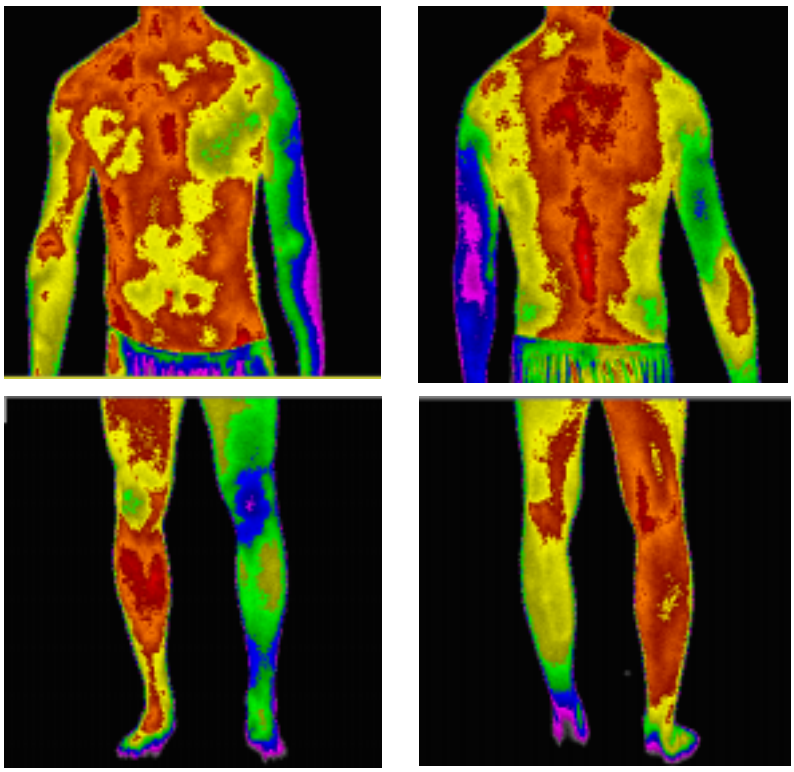
7.3 Diabetic Neuropathy



7.4 DM Foot

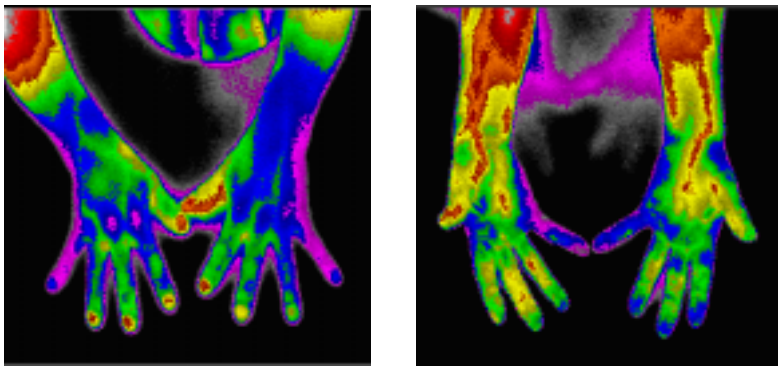


7.5 Left Hemiplegia



7.6 CTS

#1



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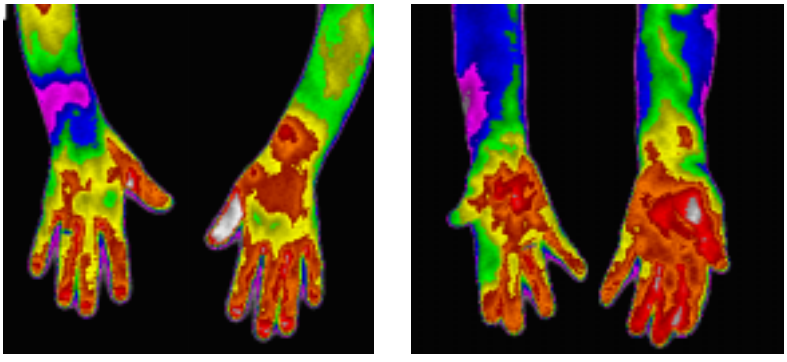
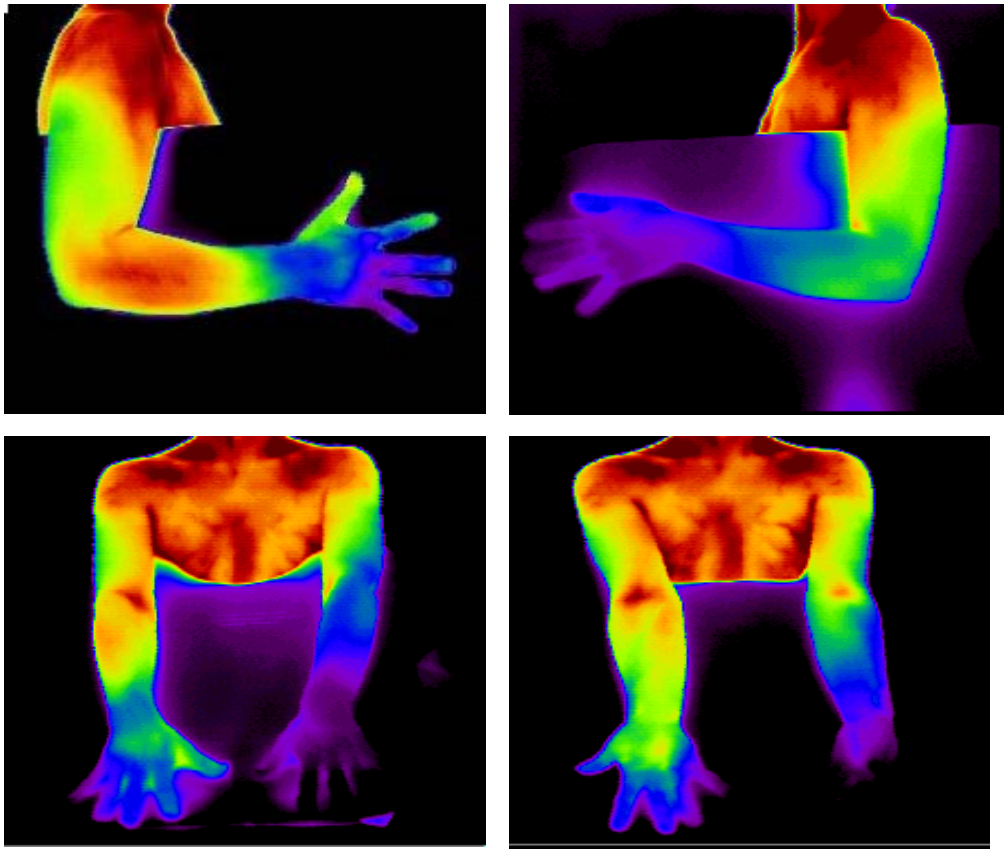


7.7 CRPS

#1



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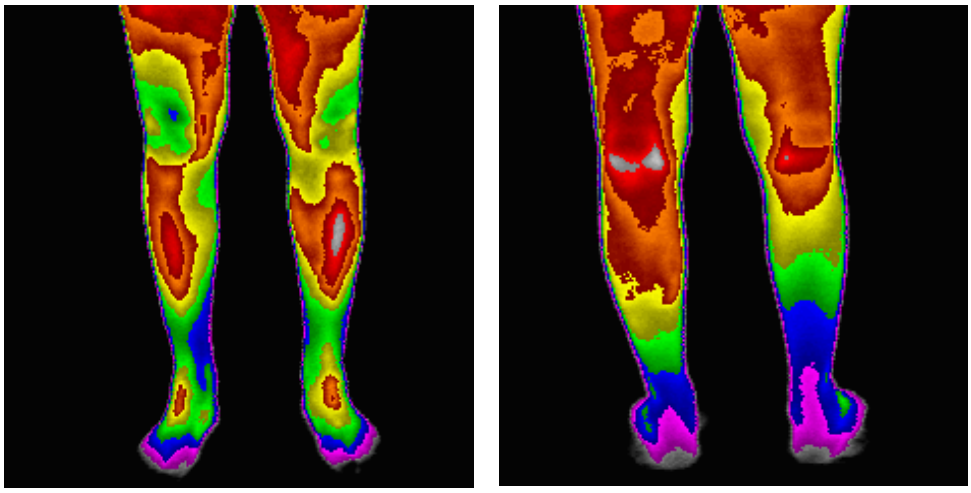

7.8 MPS

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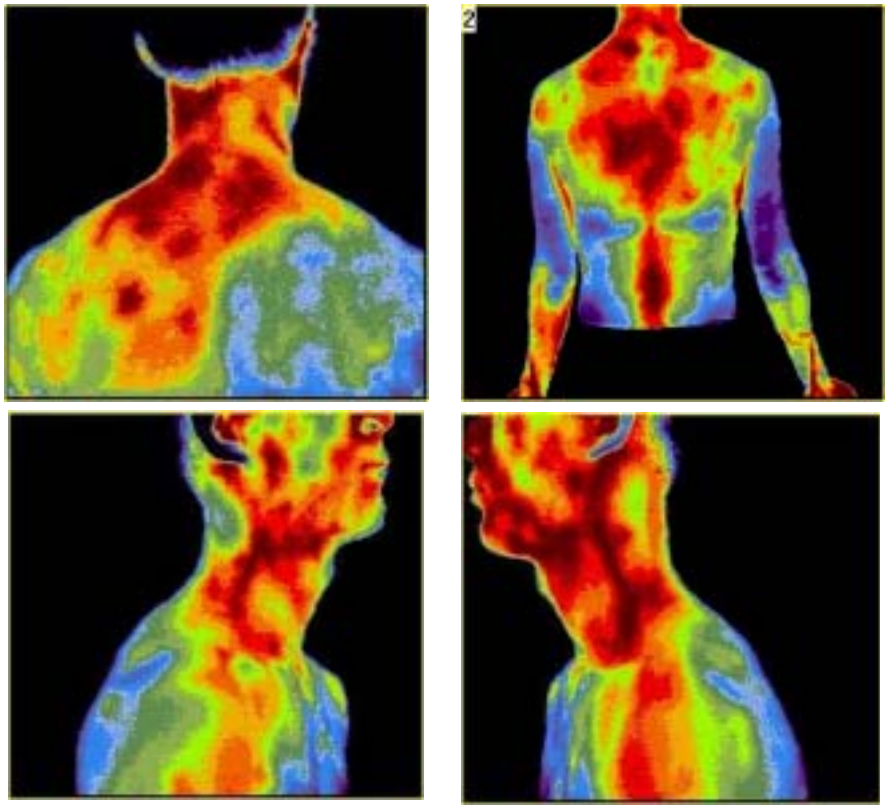

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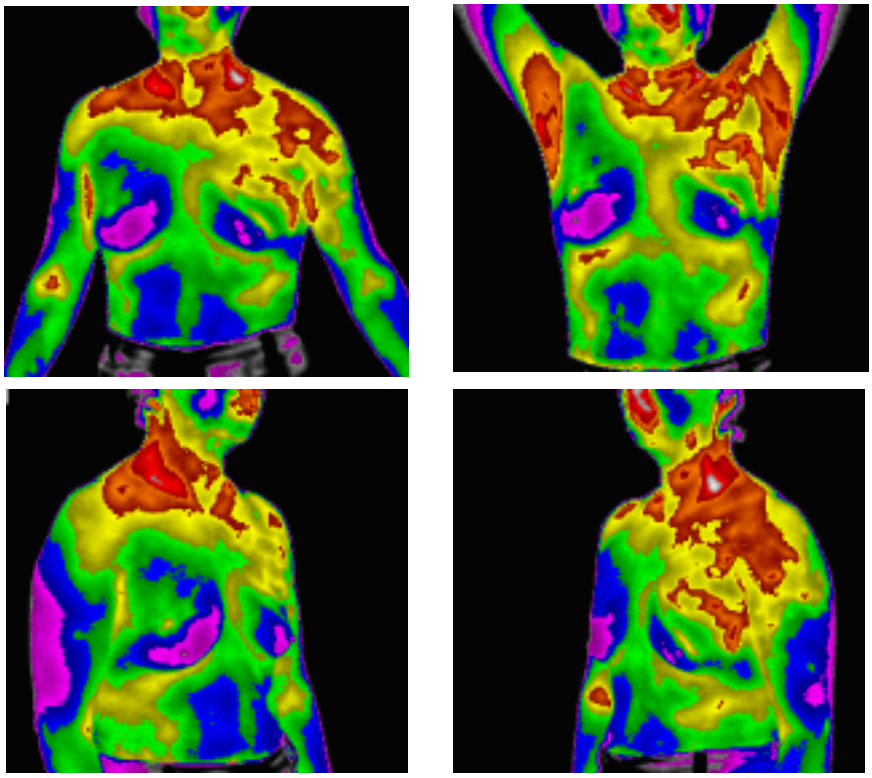
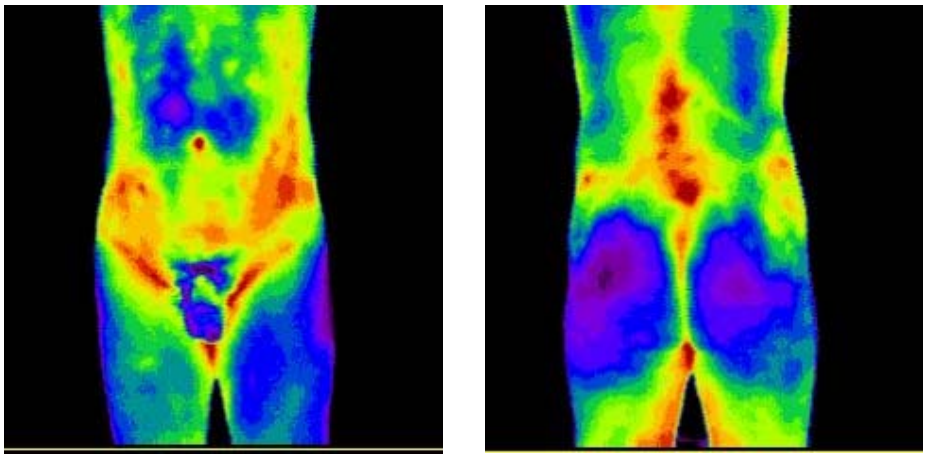
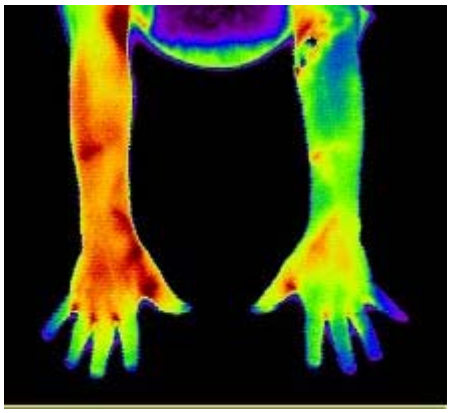


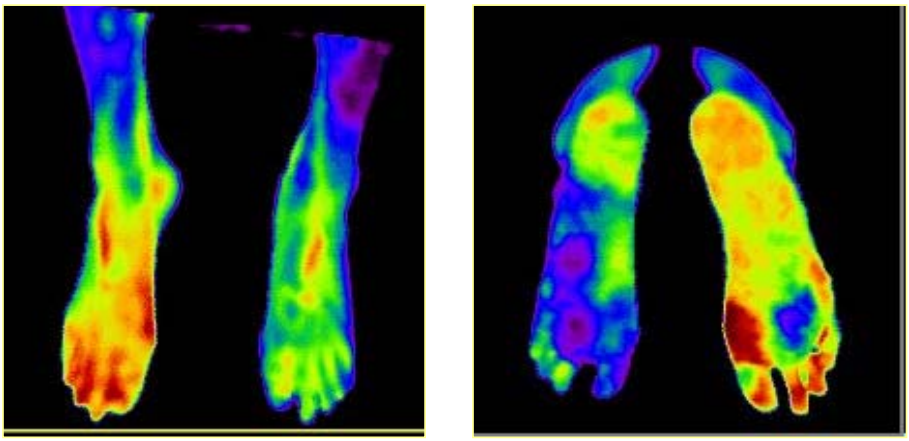
7.9 Pelvic-Hip Joint Disease



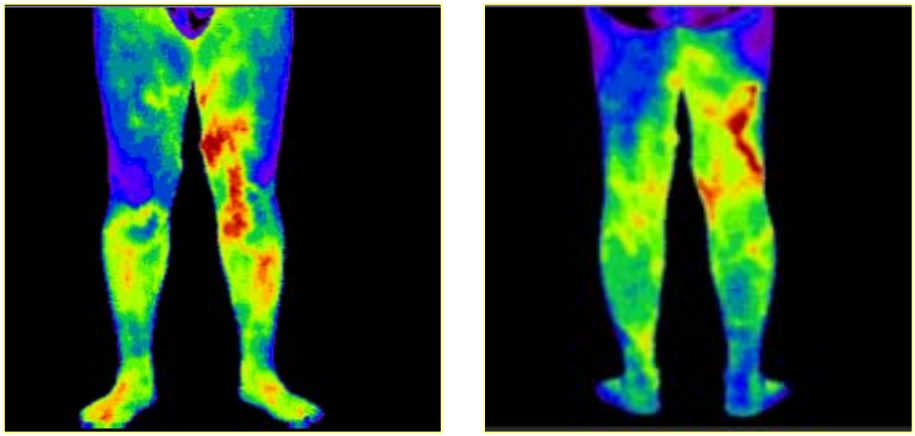
7.10 Tendinitis



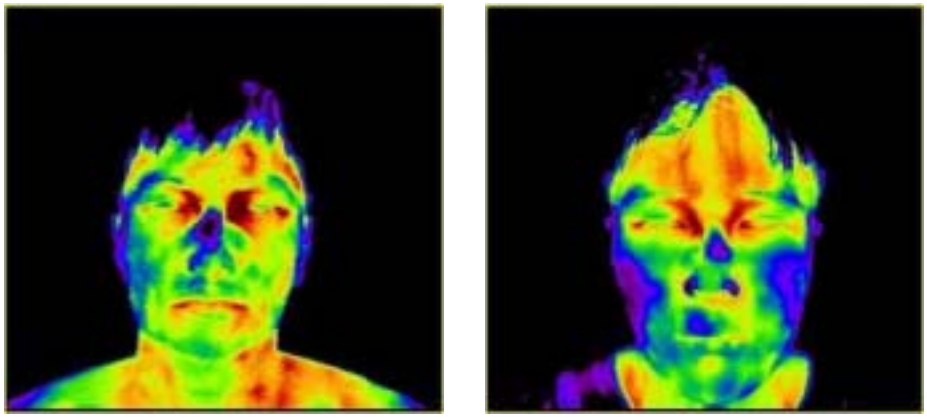
7.11 Gout



7.12 Varicose Vein



7.13 Chronic Rhinitis



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