

Role of Thermography in Management of Pain & Vascular disease

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Thermography Principle

□ What is infrared thermography?

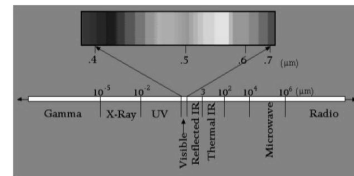
Infrared is an invisible portion of the light spectrum extending from 0.75 to 1000 microns.

All objects warmer than absolute zero (0 Kelvin or - 273.15°C) emit energy somewhere within that range.

The warmer the object, the brighter we see it in our thermal camera. White is hotter, black is colder.

The procedure is totally non - invasive and does not involve ionizing radiation. It is without patient risk.

Infra -Red Spectrum



□ Infra-Red : 0.8 μ m ~ 1000 μ m

- Near infra-red : 0.8 μ m ~ 3 μ m
- Middle infra-red : 3 μ m ~ 6 μ m
- Far infra-red : 6 μ m ~ 15 μ m <---interesting range
- Extreme infra-red : 15 μ m ~ 1000 μ m

History of Thermography

- B.C 400 Hippocrates - Diagnosis by using wet mud.
(Origin of Thermal Detection)
- A.D 1592 Galileo - Developed the first Thermoscope to measure the temperature
- 1800 William Herschel - Discovered the existence of Infrared radiation
- 1840 John G. Herschel - Studied the image process method with Infrared
He termed this image as [Thermogram]
- 1948 Leo Massopust - First used the Infrared clinically
- 1956 Lawson - Observed the thermal change of breast cancer by using vaporograph
- 1982 Pochaczewsky, Wexler - Use the touch LCD thermal image method
Diagnose the radiculopathy like Lumbar Disc Herniation etc.
- 1985 Mills - Separate each part in patients who have lumbar stenosis and show the thermal distribution

Theory of Thermography

- Skin temperature is a reflection of cutaneous blood flow under the control of the autonomic nerve system
- General mechanisms proposed for pathophysiological basis for skin temperature changes and neuromuscular disorders
 - localized muscular activity,
 - antidromic stimulation of sensory nerves
 - stimulation of the sinuvertebral nerves.

- Proposed mechanisms implicating the autonomic system
 - stimulation of the spinal parasympathetic nerves or the sympathetic vasodilator system,
 - thermal alterations resulting from sympathetic vasoconstriction, and segmental regulation by somato-sympathetic reflex.

□ Defective vasomotor mechanisms result in thermal asymmetry.

→ While nerve injury initially results in a temperature increase in the area of distribution of nerves ;
in the later stages of the injury the area becomes colder.

→ The presence of a significant temperature difference ($>0.3-1^{\circ}\text{C}$) between corresponding areas of opposite sides of the body is highly suggestive of nerve impairment, therefore, the patient serves as his own control.

Useful of Thermography

- Since thermography is non-invasive and no risk-free it is an extremely valuable tool in health care evaluation.
- Furthermore, the sensitivity of this advanced technology can often prove to be invaluable in the detection of even minimal injury. Clearly, the applications of medical thermography are numerous.
- Not only can such technology be used to make accurate and objective diagnosis, it can also be used to monitor patient program and gauge the patient's response to various treatment.

Proposed Scheme of Applications Guidelines of Thermography

- 1) Early screening tool of breast cancer, especially in younger women
- 2) Evaluation of various pain syndrome, especially neuropathic pain
- 3) Monitoring objectively the therapeutic effects from various treatments (e.g, nerve blocks, surgeries)
- 4) Determination of injury (timing, location, degree, feigned, age of injury, temporary vs permanent, compensational, etc)
- 5) Detection of extra-cranial vessel disease
- 6) Differentiation of various types of headache (migraine, cluster, cervical spine related)
- 7) Differential diagnosis of lower extremity vessel disease, neuropathies, arthropathy
- 8) Diagnosis & therapeutic determination of hyperhidrosis
- 9) Visualization of TMJ disorders and screening individuals for dental decay and cavitations without routine screening x-rays
- 10) Others;

Major Publications

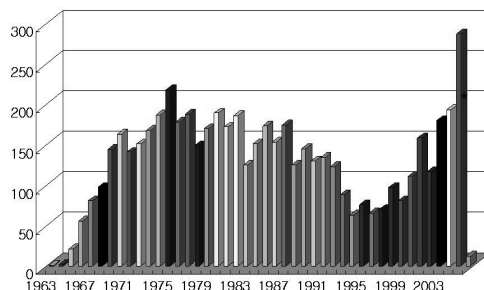


Fig. 1. Number of articles listed in medline from 1963 to 2006 (in 2006).

Fig.2. Usage of infrared thermography :
diagnostic aid vs. monitoring for therapeutic
effect and disease progression.

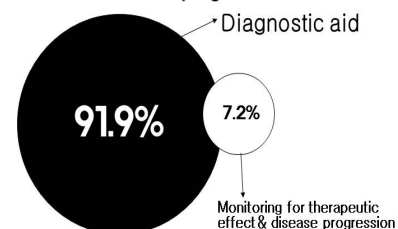


Fig. 3. Number of published articles categorized according to the organ system. (n=2993)

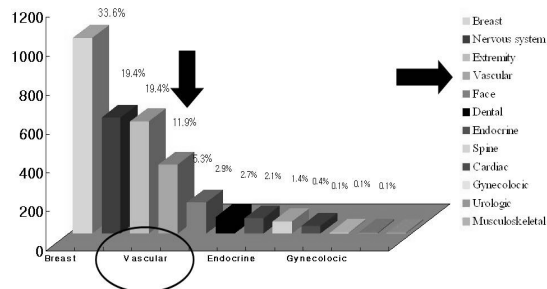
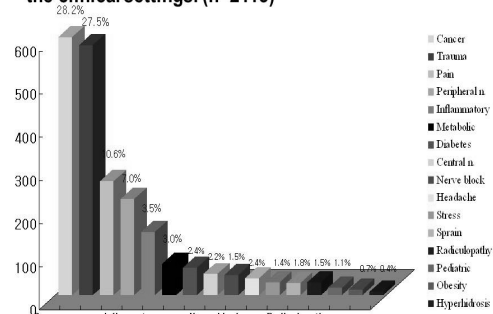


Fig. 4. Number of published articles categorized according to the clinical settings. (n=2113)



Attention of Scanning

- Suspend the physical therapy and medication before taking the thermograph
- Take off the glasses, ring, and quit smoking
- Wear the clothes loosely (Do not wear a under-wear like girdle)
- Avoid the strong sunlight
- Avoid a pungent food (Coffee, Alcohol, drinks) – before 2 hours
- Avoid the friction on skin while taking the thermograph
- Take the thermal image in 15 minutes for accustoming to the exterior temperature

Interpretation Guide (I)

Diagnosis Basics

Decisive factor of skin
Temperature → "Blood Flow"

Diagnosis Criteria

Normal skin temperature : Symmetry
(Lt/Rt) /Range < 0.3 °C

Control in skin temperature

By abnormality of nerve system, the peripheral nerve of with the reaction of autonomic nerve system affects the skin.

Determined by temperature.

Standard : Symmetry of skin temperature

Abnormal skin temperature range

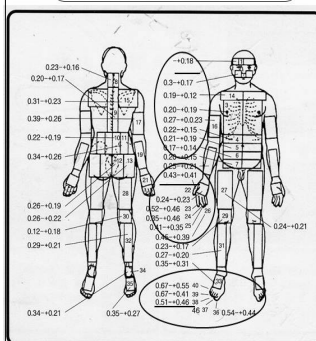
- * Muscular disease : 0.3~0.4 °C
- * Neuropathy disease : 0.5~0.6 °C

[Bilateral Disease Case]

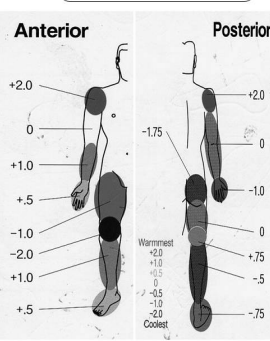
Cranial-Caudal Relationship
(Compare the temperature between upper and lower side of body)

Interpretation Guide (II)

Normal thermatome Guide



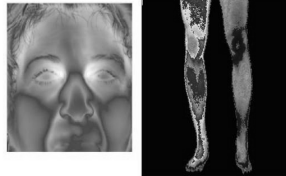
Normal thermography



Diagnostic Application

Cerebral Vascular Disease

Cerebral Vascular Disease (stroke) is the most common, neurological disease in the western world. Unfortunately, less than half of the victims experience physical symptoms of an impending crisis. Thermography offers an advanced level of examination at the metabolic level.

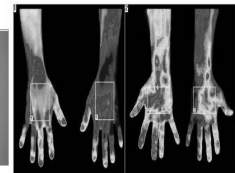


Peripheral Neuropathy

Peripheral neuropathy causes weakness, numbness, and pain in the hands and feet. It results from injury to nerves which carry signals between the brain or spinal cord and the muscles, skin, and the internal organs. There are many causes for neuropathy but everyone shares the same similar manifestations. The neuropathy can often be arrested, and sometimes cured. Proper examination and diagnosis is extremely important.



Bone Scanning



Rheumatoid Disease

Rheumatoid Arthritis¹ is not one single disease, but a catch-all diagnosis for many different causes, over 190 known different diseases, and probably more. Most are treatable, some are curable. Thus, patients must focus on selecting a health care Provider that will focus on the cause not simply treating the symptoms. It is however, vital to determine which form of Rheumatoid Disease you have through an advance examination..

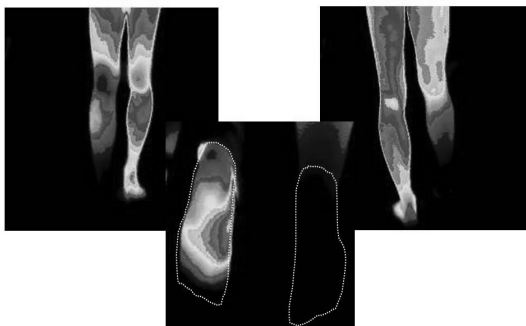


CRPS Introduction

❖ IASP diagnostic criteria for CRPS (1999)

1. The presence of an initiating noxious event, or a cause of immobilization.
2. Continuing pain, allodynia, or hyperalgesia with which the pain is disproportionate to any inciting event.
3. Evidence at some time of edema, changes in skin blood flow, or abnormal sudomotor activity on the region of pain.
4. This diagnosis is excluded by the existence of conditions that would otherwise account for the degree of pain and dysfunction.

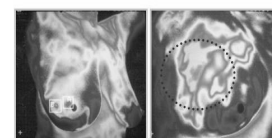
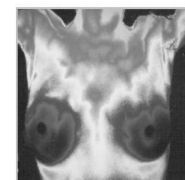
Thermography of CRPS



Breast Cancer

Every woman, 18 or 80, is at risk for Breast cancer.

Self examinations and mammography are widely promoted as recommended screening techniques. However, thermographic screening has considerable advantages such as being more effective for younger women. Additionally, a thermography is completely passive and a non-contact technique that involves no radiation hazard.



Spine Disease

- Thermography is a safe and effective means for evaluation of vasomotor instability due to irritation or injury of spinal roots, nerves or sympathetic fibers. It is to be considered an adjunctive test and not solely diagnostic except in cases of reflex sympathetic dystrophy. While one cannot extend the technique of thermography to indicate the central
- phenomena of perception of pain, it is useful in detecting associated vasomotor instability and complex pain states associated with arthritis, soft tissue injuries, low back disease or reflex sympathetic dystrophy and does provide objective data to identify dysfunction in roots that are irritated in the lumbar spine, peripheral nerves that are irritated and damage to the sympathetic nervous system. (CNS, 1984).

Controversies in Spinal Disorders

Proofs of Efficacy

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 and sciatica. Surgical treatment has also shown similar high rates of sensitivity. A large study of 805 patients with upper and low back pain confirm 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 potentials, show equal sensitivity in the diagnosis of clinical lumbosacral radiculopathy. (CNS, 1983)

Spine study [Proofs Against Efficacy]

- Sherman et al(1987) : Thermographic correlates of chronic pain: analysis of 125 patients incorporating evaluations by 10 blind panel. (Arch Phys Med Rehabil 68:273-9, 1987)
- Chafetz et al(1988) : Neuromuscular thermography of lumbar spine with CT correlation. (Spine 13:922-5, 1988)
- Uematsu et al(1988) : Quantification of thermal asymmetry : Application in low-back pain and sciatica. (J Neurosurg 69:556-61, 1988)
 - 94.7% positive predictive value of thermometry in detecting root impingement & 87.5% specificity
- Hoffman(1991): Diagnostic accuracy and clinical utility of thermography for lumbar radiculopathy. A meta-analysis. (Spine 16:623-8)

Spine study (J. Korean)

- Thomas(1990): high correlation with MRI, CT, myelography. (Br J Rheumatol 29:268-273, 1990)
- Cho(1991): useful in postoperative evaluation (Kor J Neurosurg 20:528-534, 1991)
- Diakow (1992): Thermography is useful tool in distinguishing active from latent trigger points, but thermal imaging of spinal joint dysfunction may be a compounding factor (J Manipulative Physiol Ther 15:439-41, 1992)
- Kim(1995) : thermatome has localizing value (Kor J Neurosurg 24:33-46, 1995)
- Yoo(1996): useful in deciding type of operations (Kor J Neurosurg 25:138-143, 1996)
- Cho(1998): sensitivity 88.6%, 81.4% correlation with discography, 86.4% correlation with operation finding (Kor J Neurosurg 27:237-245, 1998)

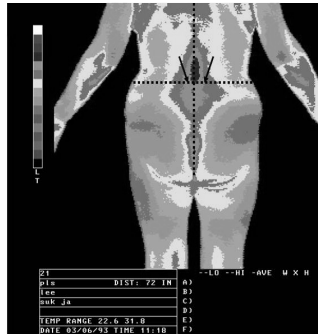
Spine study (J.Korean)

- Zhang(1999): degree of pain, severity of disc protrusion, shorter duration of symptoms correlate with greater difference of ΔT , thus useful objective tool for assessing pain (Kor J Neurosurg 28:253-258, 1999)
- Kim (2001): sensitivity 89.5%, anatomical correlation(level) with myelography(79.1%), CT(78.8%), MRI(76.6%) in 1458 patients
3 thermographic patterns of HIVD: radicular, spot, nonspecific correlation between post op study with postop results 82.4% very useful for diagnosis & for follow up study with high sensitivity & validity (J Korean Medical Thermology 13-10, 2001)
- Zhang(2001): areas of thermal change in cervical disc herniation can be helpful in diagnosing the level of disc protrusion and in detecting the symptomatic level in multiple CDH patients. (J Korean Medical Thermology 11:6-28, 2001)
- Shin(2001): Diagnostic efficacy of thermography in lumbar disc herniation with radiculopathy. (J Korean Soc Diagnostic Thermal 11:42-48)

Abnormal DT

- Between Arm
- Between Leg
- Neck
- Low Back

Minimal abnormal DT in low back

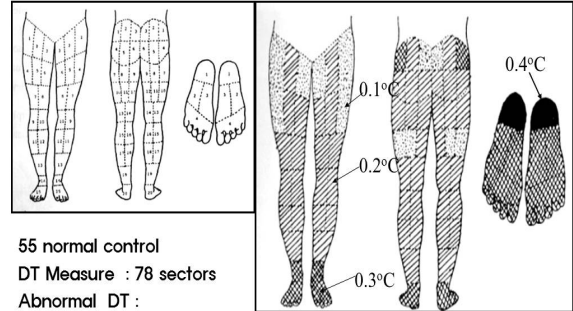


Temperature Measure:
2nd hottest area
on the Bi-Iliac line

Thermal Difference(DT)
= $0.2008 \pm 0.1861^{\circ}\text{C}$

Abnormal DT = 0.25°C
(95% confidence interval
= 0.2425°C)

Minimal abnormal DT in leg



55 normal control
DT Measure : 78 sectors
Abnormal DT :
99% confidence interval

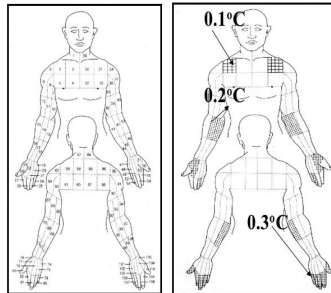
$P < 0.01$

Minimal abnormal DT in arm

50 normal control

Temp. measure:
TIO sectors

Abnormal DT:
99% confidence interval



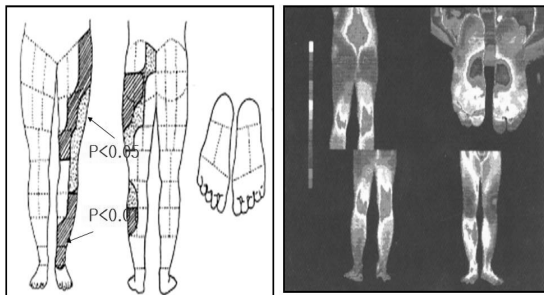
$P < 0.01$

Thermatomes

□ Thermatomes of the Lumbosacral Nerve
Roots: L4, L5, S1

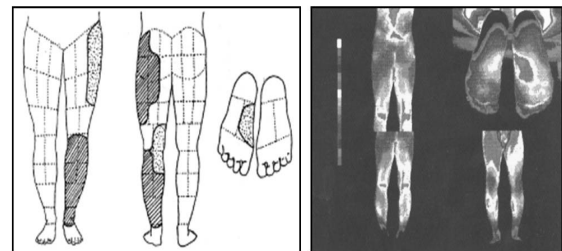
□ Thermatomes of the Cervical Nerve Roots
:C4, C5, C6, C7, C8

L4 Thermatome



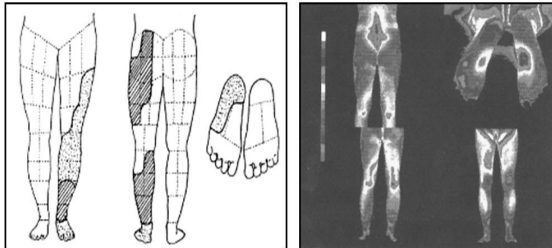
T-test with normal control and unilateral HLD L3/4 (9 patients)

L5 Thermatome



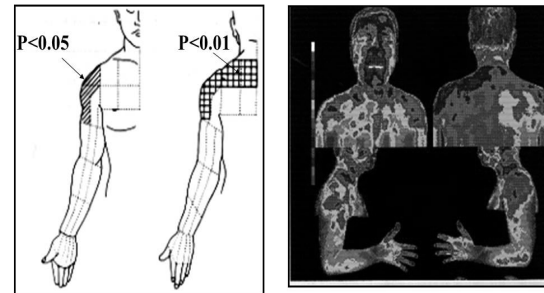
T-test with normal control and unilateral HLD L4/5 (149 patients)

S1 Thermatome



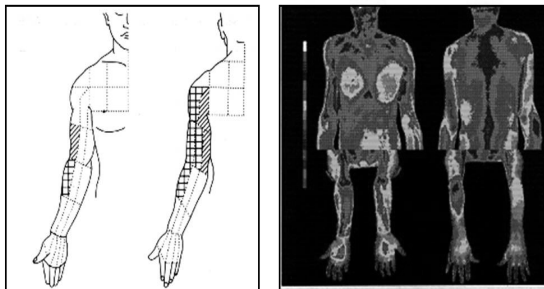
T-test with normal control and unilateral HLD L5/S1 (59 patients)

C4 Thermatome



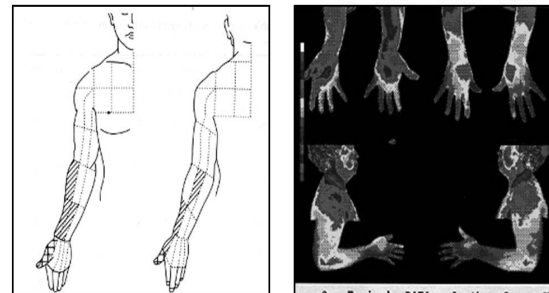
T-test with normal control and unilateral HCD C3/4 (9 patients)

C5 Thermatome



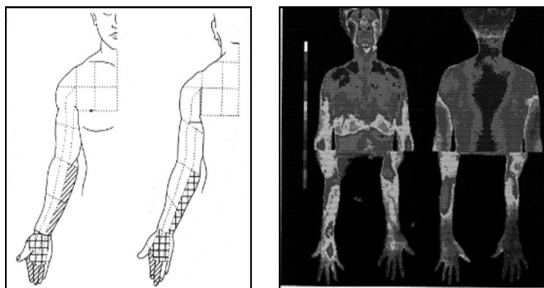
T-test with normal control and unilateral HCD C4/5 (11 patients)

C6 Thermatome



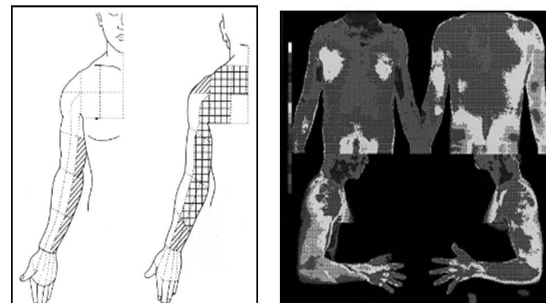
T-test with normal control and unilateral HCD C5/6 (57 patients)

C7 Thermatome



T-test with normal control and unilateral HCD C6/7 (30 patients)

C8 Thermatome

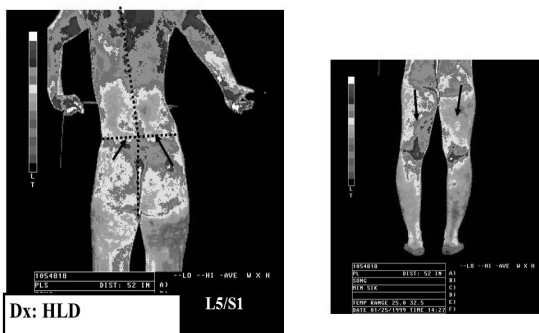
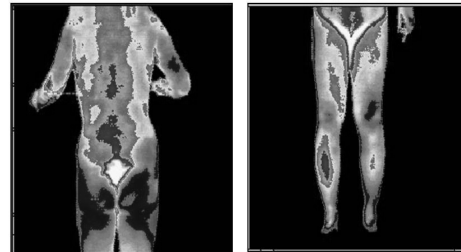


T-test with normal control and unilateral HCD C7/T1 (8 patients)

Correlation between pain scale and thermal difference in HLD

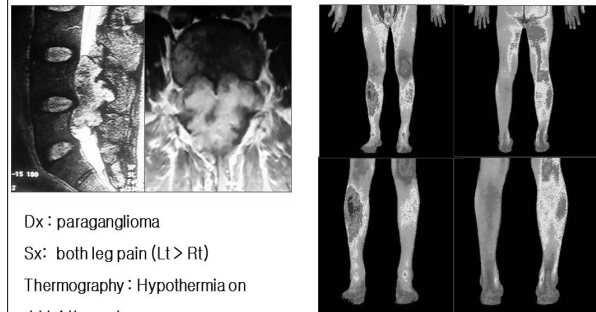
- Thermal difference between both leg is the more prominent when
 - The subjective pain score is the higher,
 - The disc herniation is the more protruded,
 - The symptom duration is the shorter
- Thermal difference between both leg is an effective pain scale to evaluate the discogenic pain

Thermal Asymmetry in Low Back Area in the Degenerative Lumbar Disc Disease



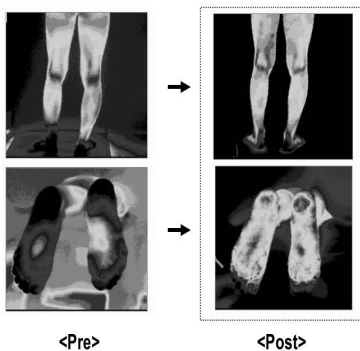
Dx: HLD
Back $\Delta T = 0.6^{\circ}\text{C}$
Leg $\Delta T = 1.3^{\circ}\text{C}$
D: 1 month

Cauda Equina Tumor Theratomal hypothermia



Dx: paraganglioma
Sx: both leg pain (Lt > Rt)
Thermography: Hypothermia on Lt L4 theratome

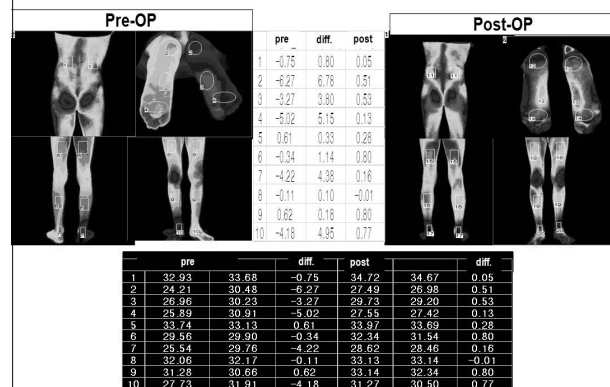
Pre-Post Laminectomy (HVD)



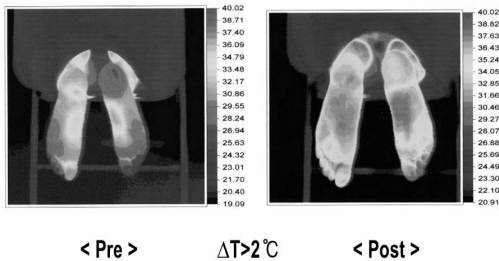
<Pre>

<Post>

FBSS : severe Rt L5/S1 radiculopathy RF/ DRG block : VAS 9 → 3



Radiofrequency Thermocoagulation (Buerger's Disease)



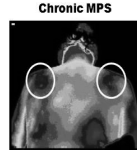
MPS (근 건막 통증 증후군)

MPS 진단 Point !!

체열 패턴

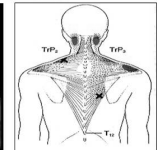
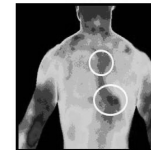
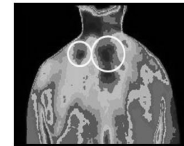
1. 국소적 Hot Spot 으로 주로 나타남.
2. 만성 통증시 Cold Spot 분포도 보임
3. Spot 과 주위 온도: ΔT 1.0 $^{\circ}\text{C}$ 이상
4. 5-10mm diameter 형성

<Case #2>



<Case #1>

Acute MPS



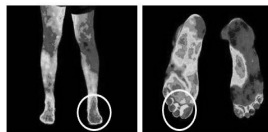
Acute Soft Tissue INJ

Acute Soft Tissue INJ

체열 패턴

1. 국소적 Hot Spot 으로 주로 나타남.
2. Inflammatory area - Hyperthermia

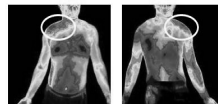
<Case #2> Ankle & Foot Inj



Hx: 3일전 수상 / Lt ankle 발바닥 뒤꿈치
Lt foot 뒷바닥을 경도로 통증 심함

<Case #1>

Rt shoulder Pain



Hx: 6일전 수상 / Rt shoulder pain 심함
X-RAY 상 Normal

Knee Joint disease

Knee disease 진단 Point !!

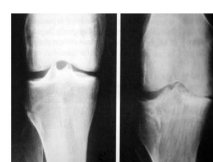
체열 패턴

- 정상 체열: 저온의 등고선 모양
염증성화 단계: 고온으로 나타남.
연부 조직 손상/ 슬관절 통증
퇴행화 단계: 극 저온현상 보임

Normal image



<Case #1>



Osteoarthritis (Lt)

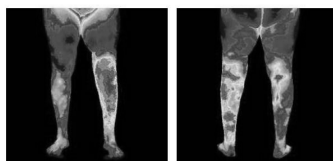
Osteoarthritis (Rt)



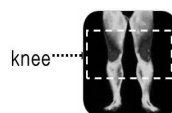
Knee disease - Chronic

Knee disease - Chronic

< Osteoarthritis (Both knee) >



Normal image



Hx: Both knee severe pain (Lt > Rt) (1/5/7)
6년 이상 무릎통증 있었으며 Lt knee는 2년전 TKA
최근 퇴행성 관절염의 부수는 통증 있음
오른쪽 무릎도 시큰거려 통증 있음

체열 이미지: Rt knee & Thigh 만성 통증으로 - 저온 체열상
Lt knee 최근 염증으로 인한 열감 - 고온 체열상

Rheumatology

Rheumatology

- 1949: 관절의 염증에 의한 체열의 변화 측정
치료의 효과 판정.
1974: Anti-inflammatory Tx 효과 확인
염증의 정도/ 국소의 온도상승 혹은 통증
Staging, 자기면역질환
1995: NSAID's Drug 객관적 효과 확인.
(Analgesic < NSAID 비교 - hand > knee)
기타: Fibromyalgia, Psoriatic arthritis

<Case #1>



Rheumatoid arthritis - 고온

<Case #2>



<Case #3>

Chronic RA case - 저온



Foot Fasciitis

Foot Fasciitis Case

진단기준

1. Acute stage : 고온
2. Chronic stage : 저온

< Acute stage (Rt) >



< Chronic stage (Rt) >



Gout

Gout

체온 분포 특징 : Great toe 주위로 고온 관찰

< Case #1 >

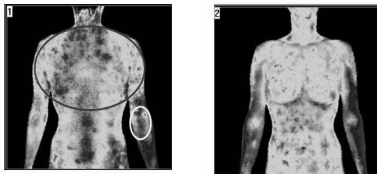


< Case #2 >



Functional disease : Fibromyalgia

기존 검사로 알 수 없는 통증 부위에 small hot spot 으로 구분 가능



C.C : fatigue, General weakness, Rt paresthesia, 지속적인 Stress

검사소견 : Hepatitis로 2년전 입원 Treatment

판독소견 : Rt hand hypothermia,

Posterior upper back area multiple hot spot -> 근섬유통 증
상과 일치 -> 외부 피부상태 이상 없음

Pain 사례

CRPS 진단 Point !!

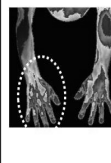
진단기준

1. Acute stage : Hyperthermia(고온)
2. Chronic stage : Hypothermia(저온).
- ** 유병기간이 길수록 온도가 감소.
- ** 3개월 이내 -1도시/6개월 -2도시 이상
8개월 이상 -3도시 이상 차가남.

특징

1. 피부 색깔의 변화
2. 피부 온도의 비대칭
3. 피부온도 : Hypothermia(저온) (>1°C)

< CRPS - Acute >



< CRPS - Chronic >



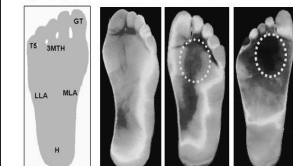
DM Foot & Breast 사례

DM 진단 Point !!

진단 중요성

1. 족부 궤양 발생 예방, 조기진단 유용.
2. Temperature
=vascularity = ANS= Neuropathy
3. 족부 온도가 높을수록 -> 신경손상에 의한
족부 궤양 발생 가능성 높음.
4. 내,외측 종아리 온도차가 없을 경우
궤양 발생률 높음. = 이원기간 길수록 온도증가

< 족부 평가부위 >



Breast 진단 Point !!

진단기준

1. Th-1(정상): 양측 유방이 무혈관 혹은
혈액관 무늬가 대칭
2. Th-2(의증): 유방 종괴 부위에 국소적 열 소견
3. Th-3(비정상): 유방 종괴 부위에 국고적 열과 주위의
맥관 소견 <온도차 2도시 이상>

< Th-1 정상 >

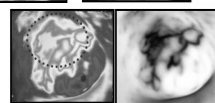


< Th-2 의증 >



< Th-3 비정상 >

국소적 열 증가
와 혈류분포



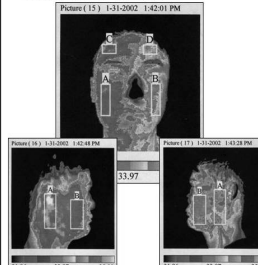
Herpes Zoster

Herpes Zoster

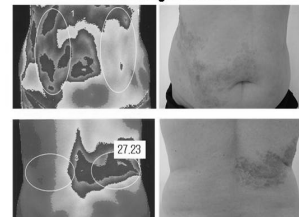
진단기준

1. Acute stage : Hyperthermia(고온)
2. Chronic stage : Hypothermia(저온).

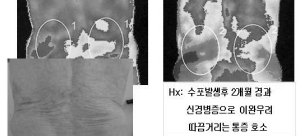
< Acute stage - Rt Face >



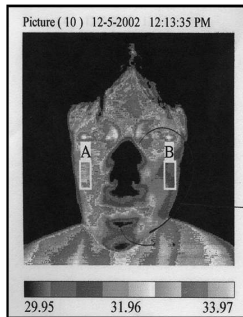
< Acute stage - Rt Flank >



< Chronic stage - Lt Flank >



Headache-Case



Normal image(Face)



Abnormal image



Facial palsy & Headache

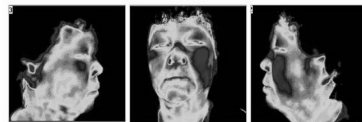
Headache

진단 유용성

1. Acute stage : Hyperthermia(고온)
2. Chronic stage : Hypothermia(저온).

- 두부 혈관의 장애 관찰
- 이마를 차게 하면 두통이 호전
- 두부와 안면부의 온도변화 관찰
- 두통의 치료효과 판정에 유용

Facial palsy



Migraine



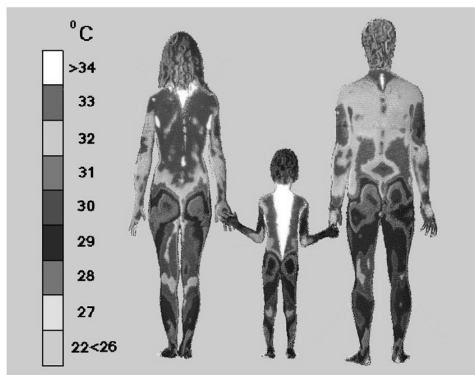
Hyperthermia around temporoparietal area

Applications of thermography in Vascular Lesion

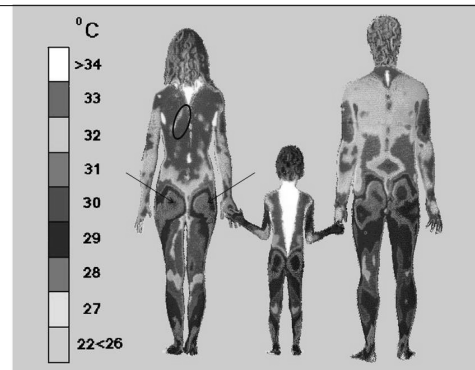
- ☐ Early detection of asymptomatic lesion
- ☐ Staging of disease progression
- ☐ Decision of therapeutic effect
 - Vasodilators
 - Sympathetic block / sympathectomy
- ☐ Decision of amputation level in ischemic limb
- ☐ Evaluation of vascular reconstruction
 - After bypass surgery
 - After vessel graft
- ☐ Follow-up after operations
- ☐ Calculation of the amount of skin blood flow

Diagnostic points about Vascular Lesion

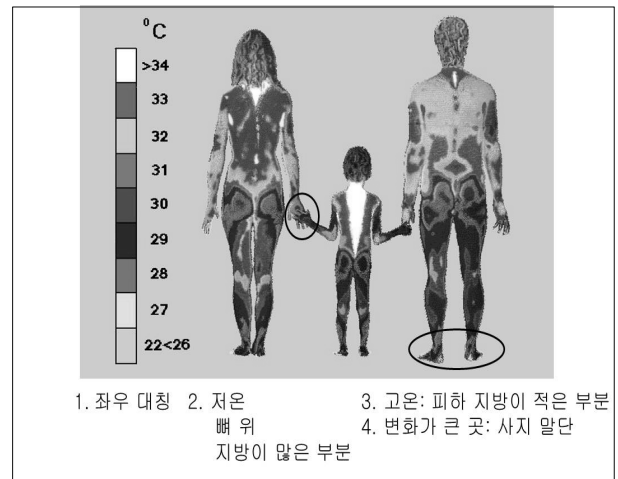
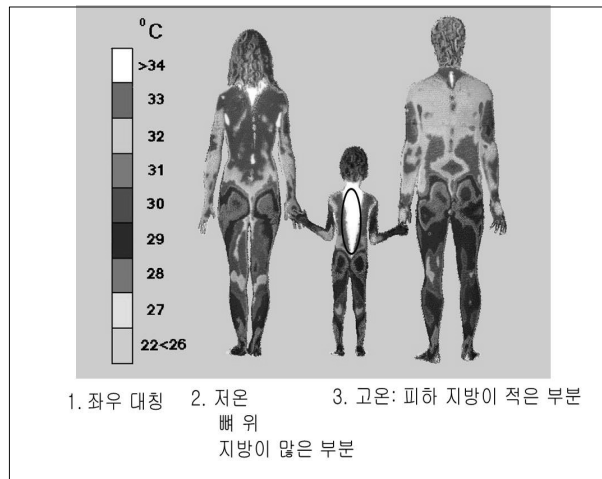
- ☐ Patterns of normal skin temperature distribution
 - Symmetric between Lt & Rt
 - Hypothermia
 - ☐ Shallow skin thickness (skin on bone)
 - ☐ Subcutaneous fat (↑) area
 - Hyperthermia
 - ☐ SQ fat ↓ area (ant. tibia)
 - Temperature variation ↑
 - ☐ Periphery of extremities (hand & fingers, foot & toes)
 - ☐ Dense vascular network and massive vasoconstrictor fibers



1. 좌우 대칭



1. 좌우 대칭 2. 저온 뼈 위 지방이 많은 부분



★ 진단 기준

- 정상피부의 체표온도 패턴과 다를 때
- 좌/우의 체표온도 차 > 0.6 °C
- 제외항목
 - 염증, 신경질환, 혈관증, 종양이 없어야 함.

폐색성 동맥 경화증 (ASO)

- 체열촬영 소견
 - 폐색부 근처에 고온부
 - 폐색부 이하는 균등한 체표온도의 저하
 - 저온역이 광범위하며, 온도 분포 양상의 변화가 적다.
 - 정상인이나 정상측 보다 체표온도가 낮음

폐색성 혈전 혈관염 (Buerger' s disease)

- 체열촬영 소견
 - 측부 혈행로가 비교적 잘 발달되어 폐색부 근처에 고온역
 - 정맥염에 의한 고온을 많이 볼 수 있다.
 - 하지의 양 발에 병변이 많다. 특히 발가락의 저온역
 - 저온부와 비저온부가 혼재한다.
 - 체표온도 분포의 패턴이 불규칙하다.
 - 손가락의 병변도 많이 볼 수 있다.

Raynaud' s disease (syndrome)

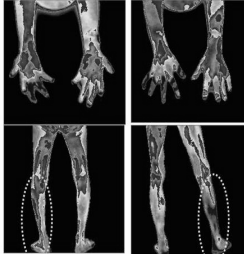
- 체열촬영 소견
 - 냉부하 검사로 확진 가능
 - 한냉 자극에서 저온이 나타남.
 - 한냉 자극에서 회복이 느리다.
 - 손가락 체표온도에서 저온역 관찰
 - 정상 체표온도 보다 매우 낮은 thermal defect를 나타내는 손가락을 볼 수 있다.

Vasculra Disease

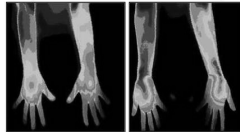
ASO 진단 Point & Case

1. Obstruction 부위 이하는 전체 저온
2. 신생혈관이 생기면 우회로 고온 형성

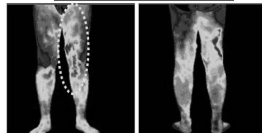
< ASO >



Raynaud's Syndrome



Varicos vein Case



• 실시간 확인 및 수술 전후효과와 판정 유용

Conclusion – 체열 응용

Its overall role in diagnosis & management of Pain of spinal origin.

- although highly correlative with patient's symptoms, and sensitive in detecting thermal asymmetry in radiculopathy and various pain syndrome associated with autonomic dysfunctions, its accurate specificity is somewhat not ideal for its use as primary diagnostic tool : rather it should be served as good objective, adjunctive tool
- unique tool in evaluation of effectiveness of treatment or procedures esp. those involving autonomic pathways
- also, useful in evaluating the course of various disease processes
- may be useful in early detection of various disorders
- may be used in clinical situation where differentiation of true pain from pseudo-pain states is necessary
- Objective of Muscular Pain & inflammatory disease.
Vascular disease, Varicose vein. Et.