

Infrared Thermographic Vasomotor Mapping and Differential Diagnosis

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When performed with proper technique and under controlled conditions, thermography (Computerized Infrared Imaging or CII) is the test of choice for mapping of vasomotor instability and asymmetry. The findings provide important clinical insights into those structures that generate aberrant sympathetic responses for pain syndromes such as Reflex Sympathetic Dystrophy (RSD), Complex Regional Pain Syndrome types I and II (CRPS), Thoracic Outlet Syndrome (TOS), Cervical Brachial Syndrome, Fibromyalgia, and Barre-Lieou. In addition, the presence of abnormalities and the distribution of findings can be invaluable in differential diagnosis of these conditions.¹

The medical community has demonstrated increased awareness of sympathetic pain syndromes over the last decade. New interventions and approaches toward alleviating symptoms in those afflicted have been tried, some with success. Even better results can be achieved through a greater understanding of which structure is initially responsible for generating the condition.

The sympathetic system, which is largely responsible for the control of surface skin temperature, innervates all tissue of mesodermal and ectodermal origin. For non-visceral soft tissues, this includes muscle, ligament, synovium, tendon, fascia, dura, disc, and peripheral nerve fibers. Other less obvious but equally important structures, such as interosseous membrane and neuro-lymphatic sphincters, can be richly innervated by the sympathetic system as well. Essentially, the innervation of the sympathetic system is ubiquitous.^{12,19}

Since one of the primary functions of the sympathetic system is to monitor those tissues that it innervates, it is not surprising that when an injury occurs to one of those structures, the system may occasionally

function improperly. Why this occurs remains speculative, but the net result is an alteration in transmembrane electric potential of the affected sympathetic nerve fibers. Direct structural injury, vascular ischemia, infection, and coagulopathy are just a few of the mechanisms that might lead to such an alteration.

From a thermographic perspective, what is important is whether the resultant vasomotor response is great enough to create a change in skin temperature of greater than 1 °C compared to the contralateral side or with respect to the surrounding dermatome, sclerotome, or vasotome. While dermatomes represent the distribution of sensory nerve fibers upon skin, a sclerotome reflects the distribution of skin galvanic impedance influenced by a visceral or non-visceral soft tissue structure. Numerous sclerotomal patterns exist. Examples of clinical conditions

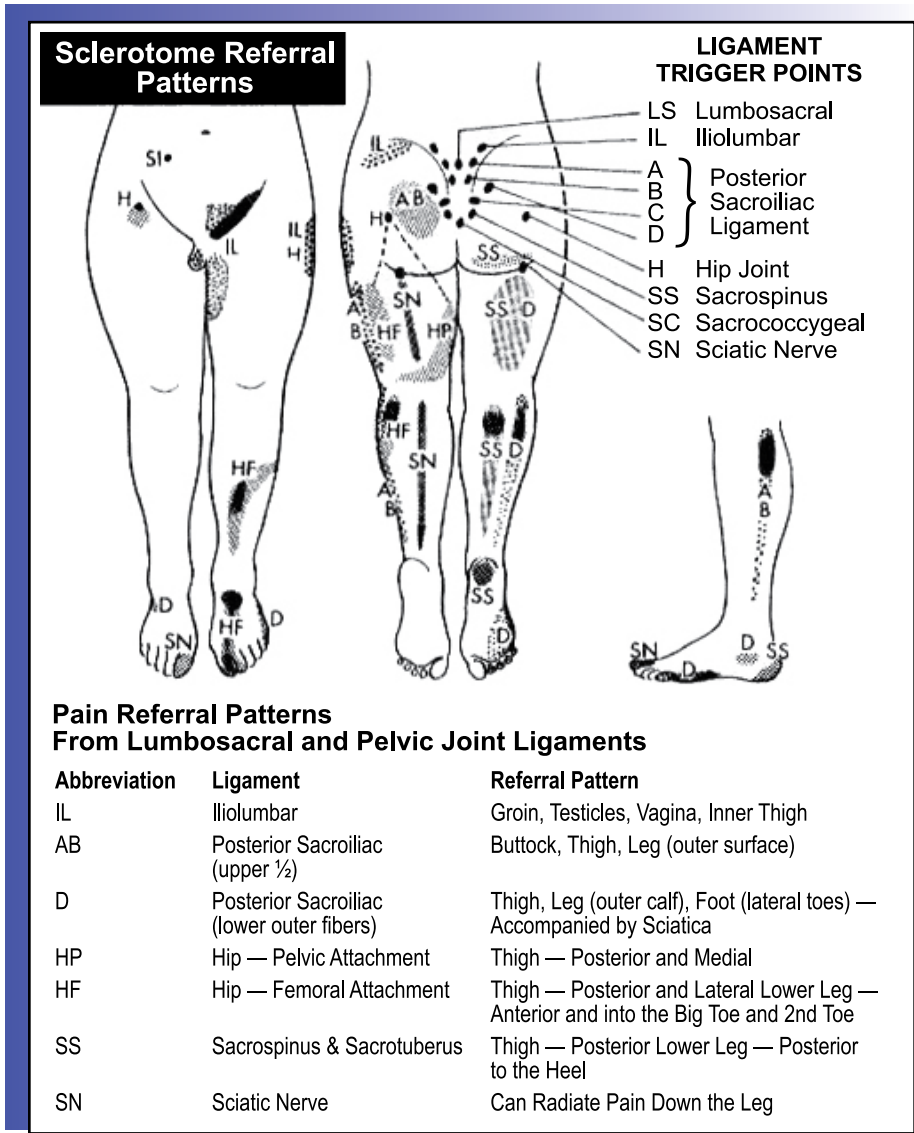


Figure 1: Lower Extremity Sclerotomal Patterns. Adapted from Hauser, R. *Prolo Your Headache And Neck Pain Away*, Beulah Land Press, Oak Park, Illinois, 2006.

with identified sclerotomal patterns (often described as referred pain) include facet syndromes, myofascial, ligament, and dural pain syndromes (Figure 1).

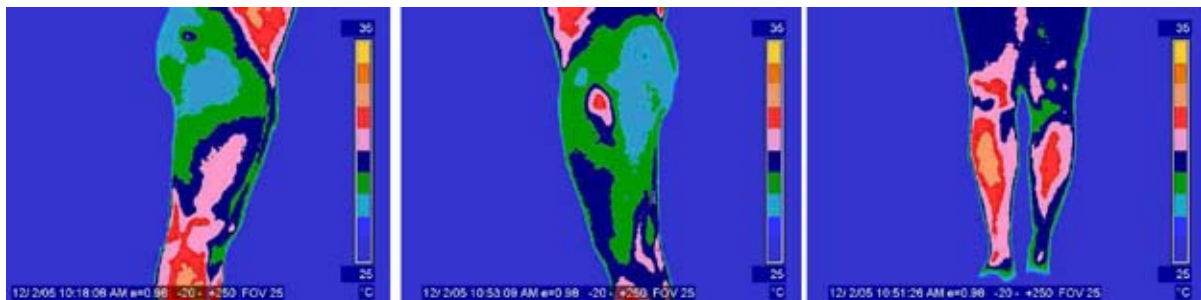
It is important to recognize that while sclerotomal patterns frequently mimic pain patterns such as herniated disc, they are not at all pathognomonic for the same. For example, a fibulocalcaneal ligament strain may very well have thermographic change that tracks in an L5 distribution (Figure 2), but that does not mean that the L5 nerve root or disc is the source of those findings. While the nerve root or disc may be the source, all structures that refer within that sclerotome must be considered when deciding which structure is responsible for the abnormality.⁵

Likewise, it is important to understand that treating any structure within the sclerotome may actually correct the abnormality. Sometimes all that is required to restore skin galvanic impedance to normal, and its associated vasomotor instability or asymmetry, is to remove the stimulus that initially generated the sympathetic response. This may mean an injection of a medicine into a torn ligament that stops inflammation or repairs the tear, or of a neurolytic agent that alleviates a persistent non-physiologic contraction of muscle. Naturally, other examples exist, such as hyaluronidase injection into a knee, and oral or topical medications that restore blood flow and modulate sympathetic tone.

Notwithstanding the above, there is also every reason to believe that treating cephalad to the most proximal portion involved will be more effective than treating caudal to it. The medical literature is replete with references demonstrating the benefit of spinal blocks for sympathetic pain syndromes. It is not, however, as clear why some blocks are more successful than others.

If a lumbar thermographic study demonstrates vasomotor asymmetry that tracks in an L34 dermatome or sclerotome, it would be reasonable to speculate that a sympathetic block at L3 would be more effective

Figure 2: *Left Lower Extremity tracking cold in a L5 distribution (in this case secondary to a fibulocalcaneal ligament strain).*



then an epidural block at L5. In addition, if the original injury was in the ankle at the medial collateral ligament of the knee, then a concurrent injection with intensive physical therapy at that locale may prove to be even more rewarding than either intervention alone. By obtaining thermographic imaging, powerful answers as to the extent and distribution of involvement can be obtained.

The thermographically generated vasomotor map also provides invaluable information for therapeutic decision-making when treatment previously based upon it fails. For example, if a lumbar block does not produce pain relief in an L5 vasomotor-mapped patient, the patient may still show dramatic response to a peroneal nerve block (another L5 innervated structure). A combination of expertise in the basic anatomy of those structures that can exert influence in the distribution of the vasomotor abnormality found, and the ability to objectify where the vasomotor asymmetry actually occurs, allows for a more rational approach to intervention that is otherwise not available.

Vasotomes represent another pattern of abnormality that the examiner must understand. They should not be confused with vasomotor instability of sympathetic origin. Vasotomes are not dependant upon sympathetic control of skin galvanic impedance, cutaneous vasculature or sweat glands, but rather represent peripheral vascular supply zones.²⁹

Likewise, local inflammatory conditions, such as a hot joint in rheumatoid arthritis or erythema associated with a rash should not be confused with local vasomotor dysfunction under sympathetic influence. By completing a full thermographic study (bilateral extremities from multiple views and corresponding spinal segments), it is not at all difficult to differentiate local inflammatory, venous, or peripheral artery abnormalities from sclerotomal or dermatomal patterns.

A normal study is also clinically helpful. It is not uncommon for a patient to be given a diagnosis of CRPS/RSD and yet be non-responsive to sympathetic block. Prolonged, hopeless medical management or invasive procedures such as spinal cord stimulators can result. A normal study helps rule out the original diagnosis, or at least suggests that a sympathetically independent pain syndrome may exist.

A localized thermographic pattern inconsistent with other recognized patterns can provide useful information as well. For example, when warming is present in the dorsolateral aspect of the foot alone

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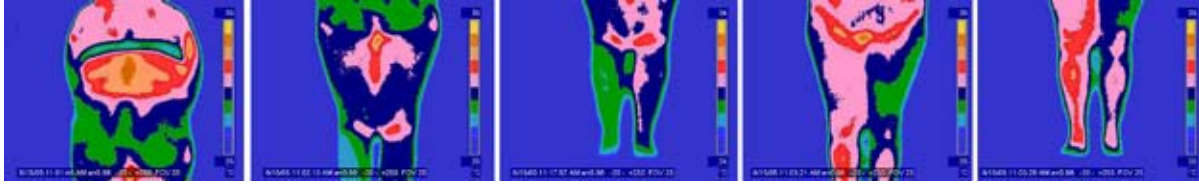


Figure 3: Note the warm left dorsal foot consistent with an Angry Back Firing C Syndrome. There was no evidence of a heat asymmetry pattern in any other view.

(Figure 3), the examiner should look for a missed fibulotalo ligament strain that, when treated, may be miraculously responsive. Since sympathetic variants such as the Angry Backfiring C syndrome (where a backfiring of the C fiber results in excess Substance P accumulation) may also create a similar picture, differential diagnostic skills must still be employed.²⁶

In the case of ABC syndrome, sympathetic block may not only fail, but can create a paradoxical worsening of symptoms, as the painful part is already vasodilated.²⁰ In this instance a pharmacologic approach that is intended to deplete Substance P or target receptors responsible for vasoconstriction, or employment of electric sympathetic block (where different aspects of the voltage gate can be targeted) may prove more effective than a chemical sympathetic block.²⁵ Whenever a paradoxical response to sympathetic block occurs, this should be kept in mind.

In addition to objectifying the presence of a paradoxical effect, Infrared Thermographic monitoring during blockade can be quite helpful in assessing if intended ipsilateral vasodilatation was accomplished. Even when a Horner's is observed with a stellate block, as many as 40% of patients do not get limb vasodilatation.¹⁸ Their lack of clinical responsiveness to the block may lead to a false impression that CRPS/RSD does not exist.

The Triple C syndrome, consisting of cold hypesthesia, cold allodynia and cold skin, is another localized sympathetic variant.^{20,27} As expected, with this syndrome Infrared Thermographic imaging reveals a localized cold asymmetry pattern. The more distal the occurrence of this syndrome, the less responsive the patient is to a spinal block. With Triple C syndrome, combination interventions, including localized therapy and pharmacologic agents, should be more aggressively used.

Diffuse vasomotor instability involving an entire limb or limb segment (Figure 4), and not confined to a particular dermatome or sclerotome, is a hallmark finding of a true RSD syndrome.^{8,32} Dural, neuro-immuno-infectious interactions and multiple generators should be aggressively investigated.²⁸ While any case of sympathetic pain with

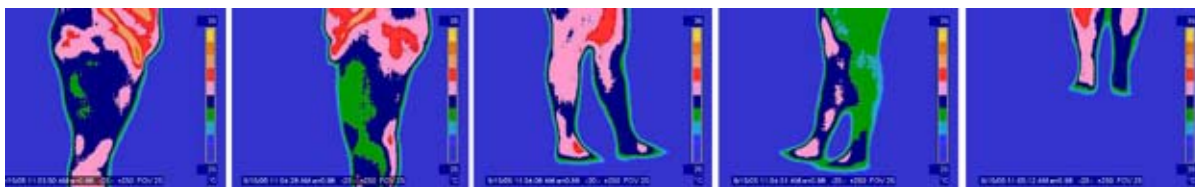


Figure 4: *Heat Emission asymmetry pattern with diffuse left lower extremity involvement consistent with Reflex Sympathetic Dystrophy.*

vasomotor instability can spread, when diffuse vasomotor asymmetry exists, symptomatic intervention with an eye towards prevention of spread, limb trophic changes, edema, contracture or Sudek's atrophy should be emphatically employed.^{4,6,14,23}

Stopping progression is one of the most effective treatments a physician has to offer in the treatment of CRPS/RSD. Early diagnosis, due to high sensitivity, is one of the great advantages that thermography offers over triple phase bone scan or diagnostic block in the management of sympathetic pain syndromes.^{10,13,22} Findings of diffuse vasomotor asymmetry should alert the physician to intercede promptly to interrupt the progression of CRPS/RSD toward stages two and three.

The physician must keep in mind that thermography is no different than any other objective study. Ultimately, it is always best to treat patients based upon both clinical and diagnostic impressions, not test results alone. This approach will help avoid the potential pitfall case wherein a localized, or clearly defined, asymmetry pattern unexpectedly shows rapid progression to escalating stages.

The International Association for the Study of Pain (IASP) has published diagnostic criteria for the diagnosis of CRPS types one and two³¹ and revisions have already been suggested.³² Whether the revised clinical and research criteria, or the original criteria are used, objective signs of vasomotor instability (changes in skin blood flow or evidence of temperature asymmetry) remain a diagnostic criterion. This is important as it is well established that palpation alone is a poor way to assess for skin temperature change.

In addition to being insensitive, palpation provides no ability to map the distribution of those changes. In cases where allodynia, hyperalgesia or barometric weather sensitivity exist, only thermography offers the ability to objectify if the vasomotor instability criterion is satisfied. In addition, the American Medical Association's "Guides to the Evaluation of Permanent Impairment" recognizes that "...regional sympathetic blockade has no role in the diagnosis of CRPS." Instead, it cites objective criteria inclusive of vasomotor change.²

Perplexed by the CRPS/RSD patient, “The Guides” suggest rating impairment based on alteration in activities of daily living, loss in motion of each joint involved, sensory and motor deficits for the nerve involved or sensory deficits, loss of power, and pain for the body part involved. While this approach attempts to sidestep the problem of objectifying which body part is involved, it is still left to the physician to address the issue.

In this light, the body part involved becomes not only a clinical issue, but also a medical-legal one. Just as a post-stroke, shoulder-hand syndrome patient may present with a swollen hand and be unable to communicate that there is proximal pain, a patient with a crush injury to the hand cannot be expected to articulate that he has vasomotor instability as far proximal as the shoulder or that the perception of compensatory proximal pain is actually sympathetic involvement of the entire limb.

Only after vasomotor mapping has been completed can the distribution of asymmetry be fully determined and the question of which body part is involved be properly addressed. There are many other difficult situations in which thermography is extremely useful in objectifying the extent or presence of involvement. These include thoracic outlet syndrome, cervical-brachial syndrome, vasomotor headache, atypical facial pain, the posterior cervical sympathetic syndrome of Barre-Leiou, and failed back syndrome.^{3,11,21}

While a sympathetic component should be considered in each of the aforementioned conditions, TOS deserves special attention. Patients who suffer from this malady often undergo extensive workups only to find the results to be negative. X-ray examination for a cervical rib is only found in a minority of cases and, when present, an even smaller number of cases show positive arteriograms.^{7,15}

Although other conditions that may be confused with TOS, such as radiculopathy or ulnar neuropathy, may be exposed, electrodiagnostic studies are usually not diagnostic for TOS.¹⁷ The vast majority of TOS cases are not due to overt vascular or lower trunk neurologic pathology, but rather secondary to numerous musculoskeletal conditions such

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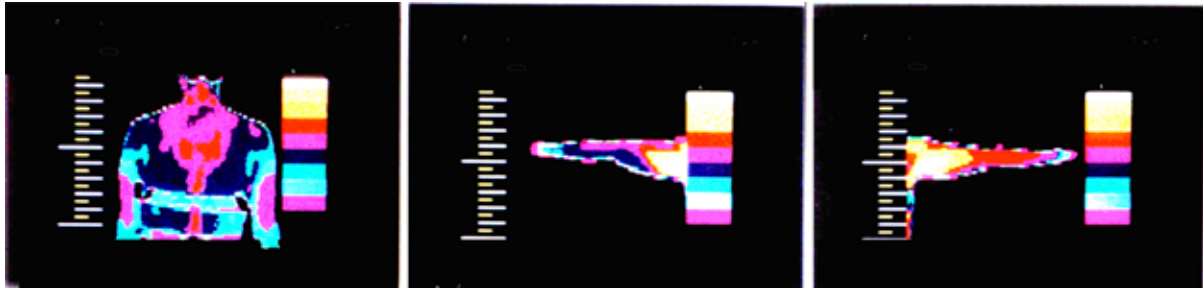


Figure 5: *Heat emission asymmetry pattern involving the medial aspect of the arm and forearm consistent with thoracic outlet syndrome. The rest of the areas showed a symmetric heat emission pattern.*

as scalene anticus spasm, scapulothoracic dysfunction with resultant tension or mechanical torque across the thoracic outlet, and cervical-thoracic interspinous ligament strain with reflex myotomal spasms or myofascial pain.

Irrespective of which of these somatic issues is the source, patients complain of cold, burning, numb sensations, typically radiating from the neck or shoulder down the medial aspect of the arm and into the fourth and fifth fingers. In some cases, vasomotor instability is visible to the naked eye with obvious skin color changes. These patients frequently respond to a stellate or cervical plexus block.¹⁶

Thermography is the obvious test of choice to objectify the presence or absence of a vasomotor instability consistent with TOS. Many surgeons have an aversion toward operating upon the TOS patient. In the absence of an absolute surgical indication for TOS, such as an obvious cervical rib that creates clear-cut stenosis on arteriography, thermography is the most cost-effective and diagnostic approach.

A positive study clearly demonstrates a heat emission asymmetry pattern across the medial aspect of the arm and forearm (Figure 5). Radiation to the medial aspect of the fourth and fifth fingers may be present as well. If a study is positive, and the clinician feels the need, then an apical chest X-ray to assess for cervical rib or arteriography can always be obtained later on.

Thermography is ideally suited for diagnosing Barre-Lieou, another common condition.⁹ There is no other diagnostic study that can objectify the presence of associated vasomotor instability. In Barre-Lieou, the posterior cervical sympathetic chain generates aberrant impulses that can result in facial heat emission asymmetry patterns (Figure 6).

There are several possibilities as to why the syndrome occurs, including a direct traction injury on the chain as in a whiplash-type injury, ischemia, or hidden infection. In any event, the result is recalcitrant

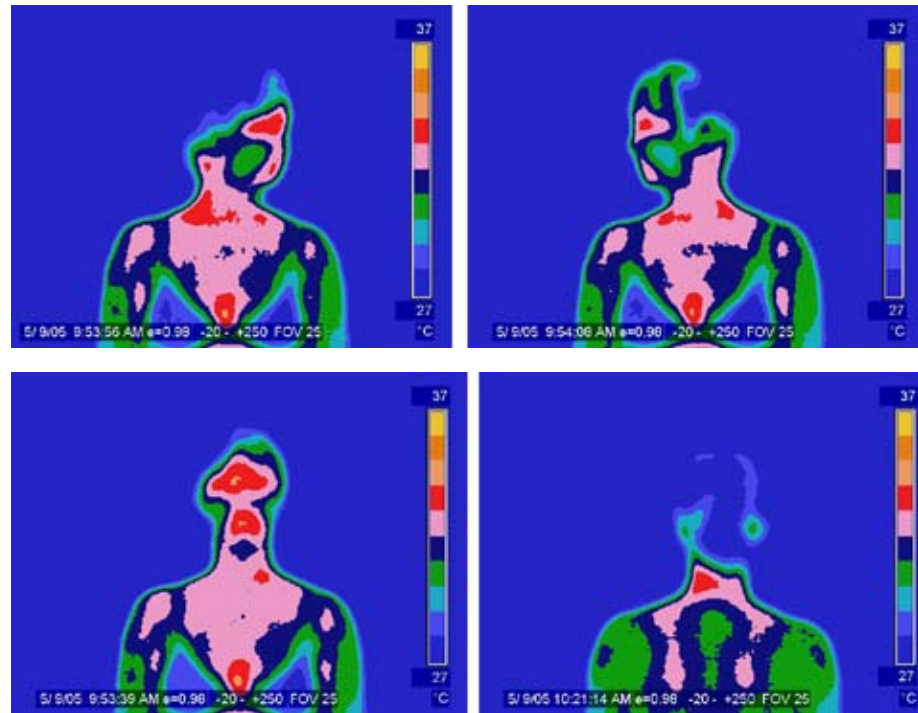


Figure 6: *There is a cold heat emission asymmetry pattern on the maxillary portion of the face and localized hot spots over the omohyoid and nuchal ligament, consistent with Barre-Lieou.*

head and neck pain — with or without scapulo-thoracic pain — associated with blurred vision, tinnitus, vertigo, or nausea.

Barre-Lieou is frequently responsive to sympathetic block. Infrared thermographic imaging of the face, cervical spine, and extremities effectively demonstrates vasomotor asymmetry in these cases. Through its unique mapping ability, thermography can also provide the physician with insight into which somatic level is responsible for the abnormality.

While proving the presence of heat emission asymmetry has great clinical significance, the benefit of objectifying its absence should not be overlooked. When criteria for CRPS are satisfied, but there is no vasomotor abnormality as with RSD, sympathetic independent pain should be more seriously considered.²⁴ In this instance, relief from sympathetic block is far less likely and alternate conditions or interventions should be considered.

Secretan's Syndrome, which consists of post-traumatic peritendinous fibrosis, brawny edema, loss of finger extensor function, and trophic skin changes, is a relatively uncommon disorder that can mimic CRPS/RSD. This condition has no vasomotor or sudomotor component, so Infrared Thermographic imaging will be negative.

Glomus tumor of the hand, due to neuro-myoarterial tumor formation, is associated with excruciating distal finger pain, cold intolerance, and pain triggered by palpation. Abnormal blood flow in the distal phalanx does occur, but typical vasomotor asymmetry patterns do not.³⁰

If it were not for the unique qualities of medical thermography, the information obtained by it would not be otherwise available. Failure to consider the objective information made available by thermography limits clinical assessment and rational decision-making when developing a treatment approach for relevant conditions. Thermography is a unique imaging study that provides the physician with invaluable information in the diagnosis, treatment, and management of patients with suspected or bonafide sympathetic pain syndromes.

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