

**TITLE:** THERMOGRAPHIC SYMMETRY AND RESOLUTION OF PAIN IN REFLEX SYMPATHETIC DYSTROPHY  
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Reflex Sympathetic Dystrophy (RSD) is a painful disorder characterized by "causalgic" pain, and symptoms of paradoxical sympathetic postganglionic activity with eventual dystrophy or atrophy of the affected distal extremity. Clinical criteria alone are insufficient to diagnose RSD. Response to local anesthetic ipsilateral sympathetic ganglion block can be misleading. "New" treatments for the pain and disability resulting from RSD are reported every few months. It is our purpose to identify objective diagnostic criteria for persistent pain due to RSD.

Approval was obtained from the Institutional Committee on Studies Involving Human Beings. Written consent was obtained from patients who fulfilled at least 4 of 7 of J. Bonica's clinical criteria for diagnosis of RSD: persistent pain; hyperaesthesia; edema; hyperhidrosis; color changes; radiographic evidence of bone demineralization; a history of injury. Patients were treated with physical therapy emphasizing active and passive ROM exercises of both extremities, and local anesthetic block of the ipsilateral sympathetic ganglia, or nifedipine 10 mg PO BID.

Subjective evaluation of pain was accomplished using a 20 cm horizontal nonnumeric visual analogue scale (VAS), with the markers "NO PAIN" (0) and "WORST PAIN" (10). Patients were asked to rate their pain at the start and end of each treatment session. Evaluation of postganglionic sympathetic function was accomplished by measuring the electrical skin activity via the psychogalvanic reflex (PGSR) of both the affected and the contralateral palm or sole. The reflex was elicited with a Valsalva maneuver; habituation was minimized by recording only the first response. Measurements were made before and after each nerve block, or once during a follow-up visit. Skin conductance was recorded as: "3"=exaggerated; "2"=present; "1"=attenuated; "0"=absent. Peripheral blood flow was examined using laser Doppler skin blood flow (LDBF) over the thenar eminence of both affected and contra-

lateral extremities. Measurements were taken before and after each nerve block, and once during each follow-up visit. Average flow over 5 minutes was recorded. Skin temperature (ST) was measured in 3 mirror-image nonvascular locations on the distal affected and contralateral extremities, and recorded at 5 minute intervals during each treatment and follow-up session. Appointments were scheduled for the same time of day during the study. Liquid crystal thermography (TGRAM) was used as a measure of distribution of blood flow. Thermograms were taken before and after each treatment or once during follow-up (after a 20 minute equilibration to the ambient temperature). Normal and affected extremities were recorded together on each plate, and were compared for regional temperature variations.

VAS scores were high ( $\geq 7$ ) upon entry into the study and low ( $\leq 3$ ) upon completion with the exception of one litigant. The PGSR, LDBF, ST, and TGRAM results were converted to the absolute difference between the affected and contralateral palm or sole. Analysis of the data recorded from each of 8 patients who have completed treatment while enrolled in the study was accomplished using ANOV with significance defined by  $p < 0.005$ . Parameters recorded from each patient upon entry into the study were compared with data recorded during the final clinic visit. Two of the patients chose to terminate treatment because of ongoing peripheral vascular problems unresponsive to our treatment. Six patients were discharged from treatment when their subjective pain was tolerable (VAS  $\leq 3$ ). In all patients, the reduction of VAS from a pretreatment score of  $\geq 7$  to a post-treatment score of  $\leq 3$  was significantly correlated with attainment of symmetry on the TGRAM.

	CORRELATION WITH RX	
TGRAM	F = 28.32	p < .005
PGSR	F = 4.667	p < .05
LDBF	F = 2.046	p < .5
ST	F = 1.781	p < .5

The diagnosis of RSD is incompletely made based on clinical criteria alone. A high VAS score and distal thermographic asymmetry which becomes symmetric upon treatment of the pain provides objective verification of RSD.

**TITLE:** THE EPIDURAL SPACE BEHAVES AS A STARLING RESISTOR and

**INFLOW RESISTANCE IS HIGHER IN SPINAL STENOSIS THAN IN DISC DISEASE**

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#### ABSTRACT

We measured the hydrodynamics of the epidural space. Analysis revealed that the epidural space behaves as a Starling Resistor where pressure tends to be constant and positive but patient or needle movement results in unstable negative measured pressure. Inflow Resistance is higher in spinal stenosis than in disc disease.

#### METHODS

We studied twenty-five patients receiving epidural steroid injection, 5 for disc disease and 20 for spinal stenosis. The infusion/measurement system used a pressure-monitoring volumetric infusion pump (IVAC 560) controlled by a portable IBM-compatible computer using specially-designed software to hold or infuse fluid in a controlled manner while pressure was measured, stored, graphically-displayed, and used to compute resistance and compliance.

We monitored pressure (P, mmHg) continuously, from skin entry to skin exit, including during injection of three test doses (1 or 3 mL each) at 5, 6, or 8 ml/min. Occasionally, 0.1 ml was withdrawn between injections.

We measured Entry Pressure before liquid injection, Final Pressure after several minutes, and Extrapolated Pressure  $P_{ext}$  (extrapolated back to before the first injection, using plateau pressures after two or more subsequent infusions). We defined Inflow Resistance only when  $P > P_{ext}$  as  $R = \Delta P / \Delta F$ , and expressed R in mmHg/L/hr.

#### RESULTS

Entry Pressure was negative in 4/4 patients in whom it could be measured before liquid injection (range -8 to -2). Final pressure remained sensitive to patient and needle motion, varying from 5 to 32. Extrapolated Pressure formed a stable measure and was not different between the two groups, ( $P_{ext}$  range=12-31, mean=19, median=19). Inflow Resistance was significantly higher in spinal stenosis ( $145 \pm 31$  SEM, range 80-428) than in disc Disease ( $43 \pm 6$  SEM, range 22-55) ( $p < 0.05$ ).

#### DISCUSSION

A negative pressure was observed on entry into the epidural space when no appreciable volume was injected during space identification. With or without injection, pressure was sensitive to motion and needle manipulation, and became progressively positive as fluid was added. After fluid injection, pressure achieved a value that was repeatable after subsequent injections, even if aspiration was performed between infusions, and this pressure was not related to presence of disease. The epidural space behaved as a Starling resistor maintaining constant pressure whenever filled to or above capacity. Finally, a stable value of Resistance to fluid infusion could be measured once the space was filled with fluid. The measured Resistance easily distinguished spinal stenosis from disc disease.