Nociception and Spinal Facilitation and Allostasis

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Osteopathic Philosophy

- The inter-relationship of body, mind and spirit
- Reciprocal networks of self-regulatory systems that maintains health and recovery from disease
- Importance of neural and fluid pathways in the actions of these networks
- Rational therapy is based on un-impeded activity of these systems
Major Issues:

• What is the pathophysiology of a “somatic (tissue) dysfunction”?
• What is the relationship between somatic dysfunction and spinal facilitation?
• How does this effect the output of the spinal cord?
• How does this effect the patient’s health?
Somatic Dysfunction (or Palpable Lesions)

- **Clinical Manifestation:**
  - Tissue texture changes
  - Increased sensitivity to touch
  - Anatomical asymmetry
  - Altered ease or range of motion

- **Pathological manifestation**
  - Edema and inflammation
Large Fiber (A-Afferent) System

- Large myelinated fibers
- Discrimination and proprioception
- Adaptation
Small Fiber (B-Afferent) System

- Small, lightly myelinated or unmyelinated fibers
- Nociception and general adaptation response
- Sensitization
Small Fiber System

• Location:
  – Dermis
  – Blood vessels and nerve
  – Skeletal muscle
  – Bone & joint
  – Intervertebral discs
  – Meninges
  – Viscera

• Activation:
  – Mechanical stress
  – Chemical irritation
Factors Activating Small Caliber, Primary Afferent Fibers

- Bradykinins
- Histamines
- Prostaglandins
- Serotonin
- $H^+$ and $K^+$
- Neuropeptides
Factors Mediating Vasodilation

• Bradykinins
• Histamines
• Prostaglandins
• Serotonin
• H\(^+\) and K\(^+\)
• Neuropeptides
Neurosecretory Function of Small, Primary Afferent Fibers

- Substance P
- Calcitonin gene-related polypeptide
- Somatostatin
Neurosecretory Properties of the Primary Afferent Nociceptor
Primary Afferent Activation

• Proinflammatory events
  – Release of neuropeptides
  – Degranulation of the mast cells
  – Chemoattraction of WBC
  – Vasodilatation
  – Release of prostaglandins
Peripheral Sensitization

- Requires initial and prolonged small caliber fiber activity

- Lowering of the activation threshold for the small caliber primary afferent fibers
Neurogenic Inflammatory Cycle
Neurogenic Inflammatory Cycle

Tissue Inflammation

Histamine  Bradykinin  Prostaglandins
Neurogenic Inflammatory Cycle

Tissue Inflammation

- Histamine
- Bradykinin
- Prostaglandins

Primary Afferent Fibers
Neurogenic Inflammatory Cycle

Tissue Inflammation

Histamine  Bradykinin  Prostaglandins

Primary Afferent Fibers

Spinal Cord

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Tissue Inflammation

Histamine  Bradykinin  Prostaglandins

Neuropeptides

Primary Afferent Fibers → Spinal Cord

Neurogenic Inflammatory Cycle
Neurogenic Inflammatory Cycle

Tissue Inflammation

Histamine
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Primary Afferent Fibers

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Neuropeptides

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Neurogenic Inflammatory Cycle

Tissue Inflammation

Histamine
Bradykinin
Prostaglandins

Sensitized Primary Afferent Fibers

Spinal Cord

Neuropeptides
Small Afferent System Activation

• **Dynamic interaction** with local tissue
  – Exacerbation of local inflammation by neuropeptide release

• **Sensitization** of the primary afferent fibers
  – Activity-dependent plasticity

• Increased “**Afferent Drive**” on the spinal cord segments
Clinical Manifestations of Somatic Dysfunction

- Tissue texture changes
- Increased sensitivity to touch
Somatic Dysfunction

• **Peripheral afferent fiber sensitization**

• **Ventral horn facilitation**
Models of Spinal Facilitation

- Gamma-loop Model
- Nociceptive Model
Central Sensitization

*Activity-dependent Plasticity*

- Triggering of phosphorylation cascades
  - Opening of voltage-dependent channels
  - Calcium influx
- Induction of immediate-early genes
- Protein synthesis, e.g. Dynorphin
- Exitotoxicity and death of inhibitory neurons: 
  *apoptosis sensitization*
Spinal Facilitation:  
*Wide Dynamic Range Neurons*

- Polysensory convergence
- Activity-dependent plasticity
- Corresponds to pain perception
Spinal Facilitation - Application

• Back pain and muscle spasm secondary to joint injury or visceral dysfunction

• Self-sustaining loop
  – Primary (joint) pain
  – Segmental facilitation
  – Secondary muscle spasm and pain
  – Further segmental facilitation
Clinical Manifestations of Somatic Dysfunction

- Tissue texture changes
- Increased sensitivity to touch
- Anatomical asymmetry
- Altered ease or range of motion
Central Facilitation Pathways

• Acute Facilitation
  – Physiological state
  – Protective in nature

• Chronic Facilitation
  – Pathological state
  – Destructive in nature
Spinal Facilitation:  
*Upstream Projections*

- **Anterolateral system**
  - Spinoreticular tract

- **Brainstem**
  - Activation of descending control systems
  - Activation of the brainstem arousal system
Raphe Nuclei

Descending Brainstem Projections
Raphe Nuclei

- Descending projections to the spinal cord gray matter
Emotions → Limbic Forebrain → Hypothalamus

Midbrain → Neuropeptides

Hormones

Opioids

Serotonin

Norepinephrine

Rostral Medulla

Medullary or Spinal Dorsal Horn

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Spinal Facilitation

- Related to small caliber fibers activity
- Develops a self-sustaining component in the spinal cord
- Controlled by brainstem activity and influenced by the limbic forebrain
The Arousal System of the Brainstem

- Rostral reticular formation

- Inputs:
  - Auditory system
  - Visual system
  - Somatic sensory system
  - Limbic (emotional) system
The Arousal System: Output

- Locus coeruleus
- Hypothalamus
The Arousal System

- The Hypothalamus (Hy)
- The Locus coeruleus (LC)
Arousal System

Sensory Stimuli

Emotional Stimuli

Autonomic Nervous System

Hypothalmic-Pituitary-Adrenal Axis

LC

Hy

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The Arousal System: Output

• Locus coeruleus
  • Sympathetic nervous system
    – Catecholamines
Sympathetic Nervous System

• Increases heart rate and blood pressure
• Prepares the blood to clot
• Dilates airways
• Decreases GI activity and libido
• Shunts blood to muscles
• Modulates the immune system
The Arousal System: Output

- *Locus coeruleus*
  - Sympathetic nervous system
    - Catecholamines

- *Hypothalamus*
  - Hypothalamic-pituitary-adrenal axis
    - Cortisol
Hypothalmic-Pituitary-Adrenal Axis

- Hypothalmus
  - Corticotropin-releasing hormone (CRH)
- Anterior pituitary gland
  - Adrenocorticotropic hormone (ACTH)
- Adrenal gland
  - Glucocorticoids (cortisol)
HPA Axis

Afferent Drives

- Circadian rhythm
- Nociceptive somatic stimuli
- Nociceptive visceral stimuli
- Emotional stimuli
Adrenal Steroid System

• Savages for energy (gluconeogenesis):
  – Proteolysis
  – Lipolysis
• Facilitates wound repair and blood clotting
• Facilitates norepinephrine
• Modulates the immune system
HPA – LC-NE Axis

Chrousos, NEJM 332:1351, 1995
Summary

• "Afferent drive" activates arousal system

• Compensatory state:
  – Catecholamine secretion
  – Cortisol secretion
  – Cytokine secretion

• Feedback pathways
Major Homeostatic Systems

- Heart rate
- Blood pressure
- Respiratory rate
- Temperature
- Blood glucose
- Ion and pH balance
- Basal metabolic rate
What Is The Compensatory Response?

- Limited alterations can occur in the homeostatic rhythms
- Chief architect of this adaptation is termed the Allostatic Systems:
  - HPA axis
  - ANS
  - Cytokines
Examples of Allostasis

- Public Speaking
- Examinations
Common Allostatic Stimulants

- Sleep-wake
- Supine-standing
- Exercise
- Infection
- Trauma
- Fright and emotional confrontation
Response To Allostasis

- Repeated “hits”
- Lack of adaptation
- Prolonged response
- Inadequate response
What Is The Price For Allostasis?

• Short-term adaptations are helpful for wound healing and tissue repair
• The gradual breakdown of feedback pathways renders long-term adaptations harmful
• “Allostatic Load” - The long term price for an uncontrolled compensatory response
Measures of Allostatic Load

- Systolic and diastolic blood pressure
- Waist-hip ratio
- Serum HDL and total cholesterol levels
- Blood plasma - total glycosylated hemoglobin
- Serum dehydroepiandrosterone sulfate
- 12 hour urinary norepi- and epinephrine levels
Cardiovascular System

Effects of Allostasis: Cortisol, Catecholamines and Cytokines

• Hypertension
• Artherosclerosis
• Left ventricular hypertrophy
• Disinhibition of the fibrinogen system
• Increased risk of myocardial infarction

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Nervous System
Effects of Allostasis: Cortisol, Catecholamines and Cytokines

- Depression
- Anxiety
- Memory loss
- Reduced cognition
- Behavioral changes
  - hostility and aggression
  - risk-taking behavior
Immune System

Effects of Allostasis: Cortisol, Catecholamines and Cytokines

- **Immunosupression**
  - Suppression of T-Cell activities

- **Autoimmune disease**
  - Facilitation of some B-Cell activities
The Metabolic Syndrome

- Hypertension
- Hyperlipidemia
- Hyperinsulinemia
  - Hyperglycemia
Key Concepts

• Acute response is beneficial

• Chronic response is harmful

• Damaged feedback pathways
Homeostasis
Allostasis

The Arousal System
- Neuro-Endocrine-Immune Axis
- Norepinephrine
- Cortisol
- Cytokines

Cardiovascular System

Nervous System

Immune System

Renal System

Gastrointestinal System
Osteopathic Philosophy

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