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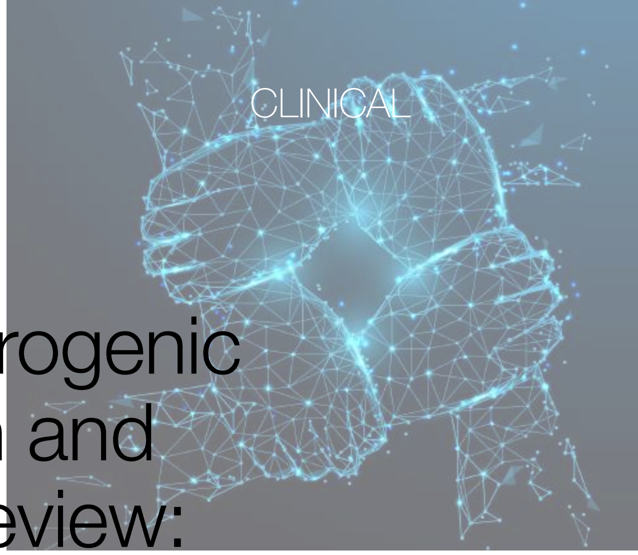

Neurodynamics of vertebrogenic somatosensory activation and Autonomic Reflexes - a review:

Part 3 A central connection

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Abstract: A review is presented of the central nervous system association with noxious sensory activation of vertebral articulations from disturbed segmental mechanics. Examples of neurological studies reflecting and supporting this physiological function are presented.

Indexing terms: Vertebrogenic; somatosensory; autonomic reflexes; subluxation; chiropractic

Introduction

An early example of the association between vertebral dysfunction and the brain was reported in 1958 by the European medical doctor Sollman. He noted functional changes in the diencephalon through manipulation of the upper cervical spine influencing sympathetic afferents and cardiac physiology. One third of his 150 patients showed positive vegetative changes. (1, 2, 3, 4, 5)

Carrick established an innovative paradigm of functional clinical neurology in a specialised and systematic extension of chiropractic. This incorporated a model of analysis, diagnosis and management involving the brain and the autonomic nervous system (ANS). This model of neurology seeks to perceptively interpret a range of traditional as well as abstruse and subtle clinical signs, to reveal an elaborate diagnostic neurological disturbance which may influence therapeutic direction and management. (6, 7)

Instances of broad vertebrogenic influence on nociception were noted by Sparks et al, who monitored this association by the reduction of pain through thoracic spinal manipulation and demonstrated functional MRI (fMRI) changes in cerebral circulation. (8, 9)

An analgesic effect was noted when specific regions of the brain were highlighted in another fMRI study following somatic stimulation through joint mobilisation of the hind limb of rats. Malisza et al noted decreased areas of activation bilaterally in the anterior cingulate and frontal cortex, as well as in the contralateral sensory motor cortex. Further somatosensory-autonomic association through the sympathetic nervous system was explored via fMRI studies by Henderson and Macefield in a 2013 report. (10, 11)

'... Mechanical disturbance of vertebral articulation can affect proprioception through the ANS as dyskinesthesia. This proprioceptive disturbance may be monitored in clinical testing. Evidence also indicates that such ANS disturbances may be moderated by addressing the vertebral dysfunction of the somatic-mechanical input, through manual corrective spinal manipulation.'

Also using fMRI imaging, a randomised placebo controlled study by Cerritelli et al provided an insight into brain activity through osteopathic manual therapy. (12, 13)

Also monitoring somatosensory evoked potentials and sensorimotor integration, Haavik-Taylor and Murphy recorded short interval intracortical facilitation, as well as inhibition, and cortical silent periods, in response to manipulation of cervical joint dysfunction (vertebral subluxations) in humans. A later study suggested that the procedure can lead to transient cortical plastic changes. (14, 15, 16)

A 2005 Russian study of 134 children who had previously experienced cervical trauma, correlated a spinoneural connection between segmental spinal excitability of pain with polysynaptic brain excitability as monitored by spino-bulbo-spinal, blink, and H-reflexes. (17)

An Interdisciplinary Spinal Research group formed in 2016 through the *Department of Chiropractic Medicine* at *Balgrist University Hospital* in Switzerland was comprised of '*multiple medical disciplines (chiropractic, medicine, physiotherapy, molecular biology, movement sciences and neuroscience)*'. They investigated several aspects of lower back pain including the wider ramifications from biomechanical somatosensory influences reflected in cortical representation and associated brain circulatory changes. (18, 19, 20, 21)

An extensive examination of the close association of the somatovisceral and viscerosomatic association with spinal manipulation and neural integration was conducted at a symposium organised by the American Academy of Osteopathy in 1989. In considering the evidence presented, the editors stated that '*the information being collected in laboratories around the world is relevant to the clinical experiences of the osteopathic profession*'. (22)

Somatosensory Centralisation

Sensory Evoked Potential and Sensorimotor

Somatosensory centralisation into the CNS is an aspect of the integrated reactivity of the autonomic nervous system in the presence of persistent pain. This results in heightened sensitivity to pain, and even to light touch. Manual therapists seek to remove that initiating stimulus of the pain, in order to normalise the noxious stimulation of the ANS. While they can be generated by mechanical stimulation, electrical activations are often used in studies which appear to induce a more robust response. (23, 24, 25, 26, 27, 28)

Central sensitization (CS) is essentially an enhancement within the CNS - especially of activated reflex circuits attributed to noxious stimulation. It includes recruitment of subthreshold synapses and neural plasticity resulting in an augmented stimulation of somatosensory input. Latremoliere and Woold state that CS is '*responsible for many of the temporal, spatial, and threshold changes in pain sensibility in acute and chronic clinical pain settings, and exemplifies the fundamental contribution of the central nervous system to the generation of pain hypersensitivity.*' (29, 30, 31, 32)

Prominent researchers in this field - Haavik, Murphy, Holt, and others, have utilised the somato-autonomic-visceral CNS pathways to monitor Somatosensory Evoked Potential (SEP) and sensorimotor changes, and their integration with spinal manipulation.(33, 34, 35, 36, 37, 38, 39, 40, 41, 42)

In further integration, Cersosimo and Benarroch note that the central autonomic networks '*are reciprocally interconnected (and) receive converging visceral and somatosensory information (that) generate stimulus specific patterns of autonomic, endocrine, and motor responses*.' (43)

Zusman noted a significant role for manual therapy, in that it may impact upon sudomotor function, heart rate, blood pressure and plasma hormones through influencing the ANS. He found that pain inhibition was through the manipulative effect of activating descending brain stem inhibitory pathways. (44)

As SEPs and sensorimotor reflexes involve brain connectivity, they can be monitored by electromagnetic evaluation which can be reflected in EEG changes. It was noted that abnormal SEPs can arise from dysfunction of a range of innervated structures such as spinal articulations, nerve roots and the trigeminal nerve. They can also involve afferent neural tracts through the periacqueductal gray region (PAG) where one of its roles is nociceptive inhibition. (45, 46, 47, 48, 49)

As well as relieving a somatic irritant, a 1995 study by Wright indicated that cervical mobilisation may activate descending inhibitory nociceptive pathways from the dorsal periaqueductal gray area of the midbrain (dPAG). These findings were supported by Sterling and colleagues in 2001. They noted excitation of the sympathetic nervous system, as well as a contrary response between the deep and superficial neck flexors. This concept has subsequently been noted by Haavik and colleagues and also by Falco and colleagues, through cervical facet anaesthetic blocks. (14, 15, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61)

In 1984 after labelling both the splanchnic as well as the intercostal nerves, Pierau and colleagues were able to demonstrate somatovisceral neural integration in a cat. They demonstrated splanchnic and intercostal nerve convergence in the dorsal root ganglia, and through the ventral and lateral horns of the lower dorsal spinal cord. (62)

Kimura and Sato state that '*Somatic sensory information from the skin, muscles and joints is transmitted to the central nervous system (CNS) by somatic afferent nerves and induces sensation, emotion and reflex responses of motor and autonomic functions*.' They also proposed that somato-autonomic reflex responses tend to explain the efficacy of spinal manipulation, physiotherapy, acupuncture and moxibustion. (36, 42, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74)

In a physiotherapy study, Bialosky et al suggest that manual manipulative intervention '*initiates a cascade of neurological responses … which are then responsible for the clinical outcomes.*' (75)

Cerebellum

Functional cerebellar changes associated with manipulative care have also been noted. In 2013, Daliqadu and colleagues interpreted readings from transcranial magnetic stimulation of the cerebellum following neck manipulation. They monitored motor sequence learning interventions to demonstrate a decrease in cerebellar inhibition and improved task performance. They enlisted 10 subclinical neck pain subjects and compared the findings with 10 healthy controls in the study. (76)

Haavik and Murphy demonstrated that even subclinical neck pain can affect joint position sense of the elbow – then further, that position accuracy improved following adjustments of the cervical subluxations. (33, 35, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87)

Thalamus

An indication of the influence of spinal manipulation on the rat thalamus was reported by Reed and colleagues in 2014 and again in 2017. This collaborative medical-chiropractic research indicated that manipulation of the lumbar spine may suppress *submedius* and *lateral neuronal activity* in the thalamus, where it may be a factor in pain modulation before nociceptive input reaches the cortex. Similar research was undertaken by others, and found to affect thalamic regions following stimulation from either acupuncture or morphine.

Other central connections of somatovisceral reflexes may involve neural plasticity with the thalamus. For instance, in 1985 a study by Vaganian et al demonstrated somatovisceral integration through somatic afferent stimulation (in cats). They found it to be inhibitory and potentially involved the thalamus. (3, 88, 89, 90)

Nociception

Nociceptive input to the ANS constitutes interoception as a physiological condition of the entire body, not just the viscera. Amongst other etiological factors to consider with this are the duration, severity, and anatomical location of the noxious input. In addition, research as to the chronicity of subtle (mild) nociceptive neural irritation upon target structures over extensive periods of time, may provide insight into the development of clinical signs of organ dysfunction which in turn may eventually lead to pathological tissue changes. (91, 92, 93)

Rather extensive autonomic changes have been noted resulting from musculoskeletal pain. These include; autonomic dysregulation, altered pain processing, modulation involving the adrenergic pathway, and catecholamine responses. A physiological response to somatic pain has been shown to affect heart rate, blood pressure, and heart rate variability. (94, 95, 96, 97)

Pain of mechanical spinal origin or degrees of it may be the most common source of aberrant sensory input in somato-autonomic reflexes. As such, mechanical back pain must be a frequent stimulator of somatosensory input to the ANS, affecting other activated ANS reflex functions of innervated structures.

A further ANS irritant could be the chemical and thermal nociceptive input of inflammation involving disturbed articulations, commonly presented for manipulative therapy. As a protopathic mechanism, it becomes an important and convenient diagnostic aid. As pain activates somatosensory and somatovisceral reflex pathways, its removal would represent a raison d'etre for the manipulative sciences. Budgell states that '*Pain in general, and perhaps spinal pain in particular, is capable of eliciting changes in visceral function which can be distressing and even dangerous*.' (98, 99)

Relief from spinal pain including cervicalgia, headaches, and radicular pain extending from the spine, are two of the more common conditions addressed by manipulation. The neurology of this pain however is heterogeneous. It is a further example of somato-autonomic interface as to the potential influence of spinal manipulation. Benarroch states that '*the interaction between the nociceptive and the autonomic systems are complex, and involve a variety of central antinociceptive, autonomic, emotional, and behavioural control mechanisms…and could provide the basis for innovative pharmacological, physical, and behavioural therapy approaches.*' (100, 101, 102, 103, 104)

In light of recent concerns over opioid addiction, it is possible that greater attention should be afforded to the physical, and behavioural model of pain management. This could be in the form of conservative initial triage for analgesic care and its broader somatosensory ramifications. (105, 106)

The analgesic effects of manual therapy were also reviewed by Vigotsky and Bruhns in 2015. They noted that different forms of manual therapy resulted in different analgesic effects and different mechanisms, but all elicit a neurophysiological response. (107)

If somatic nociceptive activation from disturbance of vertebral articulations can activate ANS reflexes, they may then have the potential to adversely affect visceral function through noxious somatovisceral reflexes. It would then seem feasible to expect that removal of the noxious stimulus to ameliorate or moderate the activated pathophysiologic somatovisceral reflexes would lead to a normalisation of those same reflexes. Burton and colleagues state that '*The sympathetic nervous system is inherently involved in a host of physiological responses evoked by noxious stimulation. Experimental animal and human models demonstrate a diverse array of heterogeneous reactions to nociception.*' (108, 109)

Proprioception - sensorimotor

Proprioception (kinesthesia) provides one of the body's most extensive sensory inputs for position sense and movement. It provides both conscious and subconscious position awareness, and is protopathic in nature. Mechanical disturbance of vertebral articulation can affect proprioception through the ANS - dyskinesthesia. This proprioceptive disturbance may be monitored in clinical testing. Evidence also indicates that such ANS disturbances may be moderated by addressing the vertebral dysfunction of the somatic-mechanical input, through manual corrective spinal manipulation.

Proprioception afferent input is supplied from Group I and II sensory neurons. Posturally, there is critical input of position from these mechanoreceptors in paravertebral muscles and articulations. Optimal proprioception is essential for equilibrium. It is a major consideration in preventing falls, particularly in older patients. Consequently aberrant proprioceptive feedback from disturbed joints may lead to balance and co-ordination problems. (69, 77, 110, 111, 112, 113, 114, 115, 116)

In noting that proprioception is also derived from muscle and other soft tissue structures, as well as vision and vestibular input. Swinkels suggested that proprioception could be disturbed by degenerative spinal articulations, due to the resultant lack of physiological proprioceptive input from the normal articular structures. (117, 118)

Apart from nociception, a noxious somatosensory barrage may also arise from other disturbed mechanoreceptors from involved structures including - *Pacinian corpuscles* (pressure receptors), *Meissner corpuscles* (movement of pressure), *Merkel cells* (light touch), *Golgi tendon organs* (proprioception) and *muscle spindles* (stretch); all combining to register an awareness of proprioception. Chronic stimulation of these structures has been demonstrated to affect ANS activity. Zimny stated that articular tissue comprises *Ruffini-like receptors* (pressure), Golgi tendon organs, and *Pacinian-like corpuscles* (pressure) are found in the joint capsules, ligaments and cartilage, in addition to free nerve endings. These disturbances can be reflected in aberrant proprioception activities. (40, 77, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128)

Sudomotor

Somatosympathetic reflexes may also be monitored through superficial temperature and sweat gland activity, in regions where it correlates with mechanically disturbed segmental spinal influence. (129, 130, 131, 132, 133, 134)

Significantly, and in confirmation of the potential for vertebrogenic conditions, Sato, Sato, and Schmidt revealed that *'the existence of spinal centres for somato-autonomic reflexes had been denied until quite recently'*. (135) General adoption of the possible principles contained in this statement seemed confined primarily to chiropractic and osteopathy.

Conclusion

In essence, the reduction of noxious somatic afference originating from these neural beds in disturbed vertebral facets (subluxation), would seem to have the potential to moderate ANS associated pathophysiological reflex influence which may be linked to visceral dysfunction.

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