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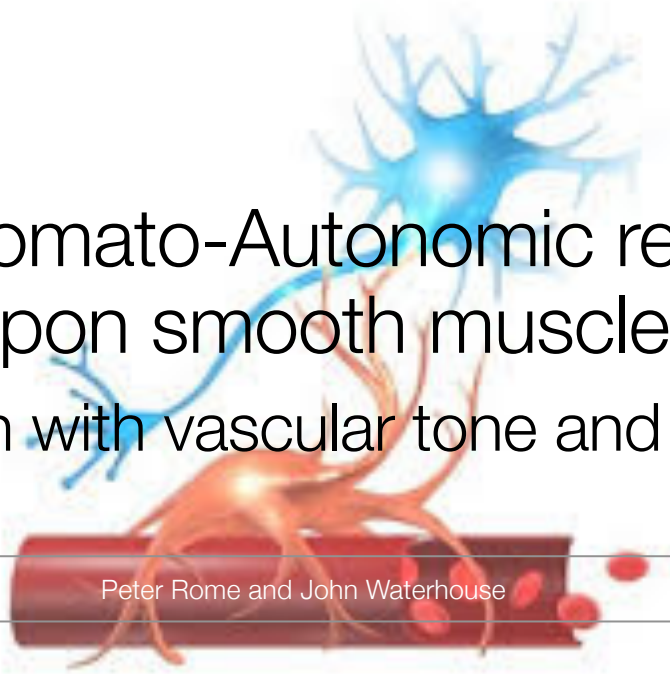

# Noxious Somato-Autonomic reflex influence upon smooth muscle:

## Its integration with vascular tone and perfusion. A review.

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Abstract: This paper is a review of some of the recognised physiological changes brought about by disruption of vascular perfusion due to noxious activation of somato-autonomic reflexes. Observations based on somatovascular reflexes are offered for considerationData Source: Primary data sources included Medline, accessed via PubMed, and the Index to Chiropractic Literature (ICL). Secondary material was sourced from the private collection of the authors. Acceptability criterion focussed on noxious somato-autonomic reflex activity as it related to smooth muscle. A considerable amount of the reference base is from medical literature. This concept has taken that material as the base upon which the hypothesis is founded. Data Synthesis: Smooth muscle is widespread through blood and lymphatic vessels, as well as in sphincters, ducts, and particularly in hollow vessels such as the gastrointestinal tract. The site or segmental level initiating noxious activation is central to this model. Results: There is potential for chronic somatic irritation to activate smooth muscle contraction (or indeed dilation) resulting in possible diminution of circulatory supply of vascular constituents with the possibility of an ischemic effect leading to functional changes in the supplied structures. Conclusion: One of the primary sources of noxious somatosensory bombardment is from disturbed mechanoreceptors associated with vertebral segments, particularly the articular facets. This is apparent with major trauma, but even subliminal activation from disturbed vertebral mechanics is thought to be a common factor. This appears to be the first time such an hypothesis has been put forward. It may however serve as one of the factors in explaining some of the more obscure symptoms and signs that are reported in chiropractic clinical studies.

Indexing Terms: Autonomic nervous system; smooth muscle, Somato-Autonomic reflexes; vertebral subluxations; chiropractic.

### Introduction

> *'Understanding the relationship between the ANS and vascular system may provide new and effective therapeutic strategies for vascular diseases.'* (51)
>
> '*The crosstalk between autonomic nervous system and blood vessels.'* Sheng Y, Zhu L, 2018.

Smooth muscle comprises the tunica media of the vascular systems throughout the body. It also constitutes the contractile layer in various internal structures including the kidneys, glands, and hollow organs such as bladders. (1, 2)

Neurophysiological influence on circulation through vasomotor reflexes has the potential to influence supplied anatomical structures. This discussion focuses upon the perfusion and effect on these target regions particularly the effects of ischemia. We postulate that with activation of noxious somato-autonomic reflexes, vascular perfusion at the capillary level may be disrupted

*... the chiropractic, osteopathic and medical evidence produced in this review tends to support the chiropractic subluxation model as a factor in some dysfunctional visceral conditions. It is noted that there is a dearth of evidence to the contrary'*

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to the extent that tissue function in the vascularised sites may be compromised. (3, 4, 5, 6, 7, 8)

The normal functioning of the smooth muscle can govern the health status or homeostasis of the body and of particular structures and organs within it. Even skeletal muscle and cardiac muscle have vascular supplies controlled by smooth muscle in the tunica media, as do the larger blood and lymphatic vessels. These vessels carry a range of humoral, hormonal and metabolic elements including neurotransmitters, oxygen, amongst many others. (9, 10, 11)

The autonomic nervous system essentially monitors and coordinates all physiology. A normal tone of autonomic reflexes seeks to maintain a stable physiological equilibrium of physiological functions including the cardiovascular system. Innocuous somatosensory activation may be initiated by chemical, mechanical, thermal, cutaneous, acupuncture, joints, electrical and muscle afferent sources to maintain physiological tone. (12, 13, 14, 15, 16, 17, 18)

Noxious neurosensory insult triggering pathophysiological somato-autonomic-vascular reflexes from vertebrogenic origin have been be recognised as a potential pathophysiological phenomenon. It is submitted that chronic noxious input may at times be subliminal and as such, research on this topic seems to attract only limited attention. (19, 20, 21)

It should be noted that regardless of the wide associations reported in this paper, there is no claim of a panacea or even a primary claim of subluxation-related factors in all conditions of ill health. However, given the volume of published evidence, we suggest there are grounds for ongoing research to further explore the possibility that due to the somatosensory influence on the neural and vascular systems through the autonomic nervous system, that subluxations may be a contributing factor in a range of conditions or their symptoms and that their correction appears to be of benefit to patients.

## Review

In 1920, Wernöe noted that neurovascular occlusion with pain occurred in areas of the head. (22) Other such sites over the body became known as Wernöe zones. In 1950, Adams-Ray noted this ischemic reflex being associated with the C4 segment and cardiac pain. On the basis of this vasoconstriction, it would be fair to conclude that muscular and internal visceral structures could undergo a similar pathophysiological phenomenon. However, demonstrating this would require rather complex or invasive imaging, especially in the clinical setting. (23, 24, 25, 26)

In 1960, Wright and colleagues monitored vasomotor tone and noted topographical patterns of vascular activity. They considered them to be functional rather than anatomical and followed similar patterns to sudomotor activity – a finding consistent with that of Vincenzino et al in 1994. (27, 28)

Subsequently studies by Korr et al suggested that the patterns of aberrant areas of sudomotor and vasomotor activity may reflect subclinical and asymptomatic sources of afferent sympathetic bombardment of sensory input through the dorsal roots. (29)

In describing the neural ramification of a vertebral subluxation ('*osteopathic lesion*') in 1947, Korr also noted '*changes in local circulation and in the exchange between blood and tissues*.' (30)

In the early to mid-1960s, European medical papers reported this vertebrogenic or somatovascular association. (31, 32, 33, 34, 35)

## Vertebrogenic factor: the subluxation

Perhaps some of the most supportive medical evidence for this somatovascular model has been provided by Gongal'skii and Kuftyreva. (36) They attributed vertebral subluxation with activation of the autonomic nervous system in association with the vascular changes. The complete abstract is included as the full paper was not translated.

> '*Microcirculation disorders may cause functional deviation in gray matter cells of the spinal cord. One of the setting moments of the disorders is the subluxation of a vertebra as a result of the disturbance in carrying ability of the spinal disc in case of spinal osteochondrosis. In this position the soft tissues of the spinal motional well innervated segment are stretched, which induces irritation in the segmental part of the spinal cord including vegetative nervous structures. Subluxation of a vertebra causes changes in the structures and in the microcirculation vessels which grow simultaneously and this permits supposing their interrelation*.'

In this medical paper, it is emphasised that Gongal'skii et al specifically mention subluxation of vertebrae in association with '*irritation in the segmental part of the spinal cord including vegetative nervous structures.*' Further, these subluxations '*cause changes in the structures and in the microcirculation vessels which grow simultaneously and this permits supposing their interrelation*.' It is stated further that '*microcirculation disorders may cause functional deviation in gray matter cells of the spinal cord.*' (36)

A 2011 study using brain PET scanning at the Cyclotron Nuclear Medicine division at the Tohoku University in Japan, found that chiropractic spinal adjustments of the neck could influence glucose metabolism in the brain in association with sympathetic relaxation. They also found that cervical muscle tone and salivary amylase were also influenced with cervical adjustments with resultant pain reduction. (37)

In 1985 and again in 1995, Vernon reviewed the vascular role in vertebrogenic migraines a condition which exhibits a cervicogenic role in a somatovascular association. A further study reported in 1995 involving 729 subjects noted the efficacy of chiropractic cervical adjustments. The Pubmed medical index records 328 papers on the topic of cervicogenic headaches. (38, 39)

Detailed discussion on the vertebral subluxation with references to somatovascular changes with vertebrogenic associations are provided by Senzon.(40) He notes that '*the peripheral distribution of the post-ganglionic fibres follow the course of the larger arteries, supplying short sections of these vessels with single axons which terminate in the muscular layer of the vessel.*' (41, 43, 43)

Senzon outlines the vertebral association of vasoconstriction under the sympathetic nervous system by stating:

> *'The vasoconstrictor fibres belong to the thoraco-lumbar (sympathetic) division of the involuntary nervous system. These constrictor fibres arise from groups of nerve cells situated in the lateral horns of the spinal cord, extending in man from the first thoracic to the second or third lumbar segment inclusive. All the arterioles of the body wherever situated are supplied with filaments whose ultimate source is this relatively limited region of the central nervous system.'* (40)

In relation to vasodilation, Senzon explains further that:

> *'The sensory fibres, through which the antidromic impulses of vascular dilatation are conveyed, are distributed anatomically on a segmental level throughout the length of the spinal cord through each posterior division of each spinal nerve.*

*It becomes evident that segmental skin temperature differentials represent zones in which, because of reduced dilating tone, the vasoconstriction of the blood vessels of the skin is seen to dominate in the affected area …*

*… the affected area of skin could lose its dilating tone in a sharply segmentalized manner if this is an accurate description of the mechanism of the antidromic impulse and vasodilatation'.* (44)

A clinical example of smooth muscle dysfunction with a declared vertebrogenic association was noted by Grgić in 2013. This paper noted cervical segmental dysfunction (vertebral subluxation, functional blockade) associated with swallowing difficulties – dysphagia. Manual therapy (vertebral adjustments, manipulative therapy) is listed among the therapeutic options. (45)

## The somato-autonomic vascular association

Although related to more serious spinal cord injuries, Mathias and Bannister note that injuries above T5 leads to sympathetic outflow affecting blood pressure homeostasis and that somatic stimuli above this level causes autonomic dysreflexia which unmasks primary cutaneovascular, viscerovascular, and somatovascular reflexes. However, in this instance we seek to consider an association between chronic but milder (simmering) dysreflexia of smooth muscle response from a long term noxious somatic stimulus, and the effect that might have on target structures. The activation level to such reflex response would be the key to such a concept. (46)

Wecht and Bauman note that autonomic influence in cardiovascular responses to sympathetic activation between the T1-T5 regions is different to the vascular response from autonomic activation between T5-L2. These two segmental levels can have a different effect on cardiovascular control and associated symptoms in patients dependent upon the level of spinal cord injury. (47)

The vascular smooth muscle distribution throughout the body is essentially as extensive as the body's neural network with which it is integrated through the autonomic nervous system. The ANS can be influenced by sensory activation which raises the possibility of somatosensory influence upon any structure with smooth muscle via this integration of somato-autonomic reflexes. (48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59)

A review of smooth muscle function in vascular and lymphatic walls exposes the potential for pathophysiological disturbance of visceral structures and function. It would also tend to explain some of the clinical features which appear to respond to correction of mechanically dysfunctional, nociceptive spinal segments such as segmental adjustments of these vertebral subluxations. Apart from circulatory regulation through the vast vascular network, other structures reliant on smooth muscle function include sphincters, glands, follicles, kidneys, uterus, and the eye (ciliary muscle), as well as the hollow organs such as bladders, ducts, and the gastrointestinal tract. Consequently, some of the concepts presented here have been based on well-reported clinical observations. (60)

As smooth muscle influences so many these physiological functions, activation of sensory neurophysiology at a particular segmental level may then be involved with altered function of an affected organ. This may be present as symptomatic of dysfunction of structures or organs due to the integration of smooth muscle in their function(s). As such, the extensive complex of smooth muscle has a vital role in the physiological state of homeostasis. (61, 62, 63, 64, 65, 66, 67)

## Autonomic influence of smooth muscle

Particular consideration is also given here to the sheets of smooth muscle layer in vascular and lymphatic vessels. This tunica media functionally controls the health of the organ or structure supplied through vascular integration with a rich neural network. (48, 68, 69, 70, 71)

Under aberrant somato-autonomic reflex stimulation, the contractile property of smooth muscle may underline its potential for a localised ischemic effect on target structures. The neuropathophysiology associated with persistent smooth muscle constriction (or dilation) through neurological tone may disrupt physiological integrity of that target structure. Although there are both intrinsic and extrinsic factors that influence vascular tone, neural innervation of smooth muscle is one of those factors. This could be considered a separate but less direct neurological influence to a target structure or organ in addition to the direct spinal nerve and parasympathetic vagus supply. (72, 73)

Sato et al state that '*Unwelcome autonomic effects of somatosensory activity include, amongst many more harmless examples, the severe symptoms of circulatory failure, sweating, nausea, vomiting etc., as a consequence of excruciating visceral pain.*' Evidence was also found relating to the somatosensory dilation of blood vessels. O'Herron et al stated that '*Neural activation increases blood flow locally.*' (74, 75, 76, 77, 78, 79)

Neural influence is not limited to the smooth muscle layer in vascular walls, but may also influence vascular endothelial function. Sheng and Zhu state that '*The autonomic nervous system is involved in mediating the behaviour of the endothelial function… In the development of vascular diseases, the co-existence of ANS abnormality and endothelial dysfunction suggests the complex interactions between them.'* They also state that *'The dysfunction of the autonomic nervous system could be a risk factor for vascular diseases and the overactive sympathetic nerve is detrimental to the blood vessel.*' In essence they confirm that the ANS is essential for homeostasis. (51)

Although associated with endothelial cells, the role of pericytes (mural cells) has not been considered in this dissertation. It is noted that these cells are present in blood vessels but not lymphatics. (81, 82, 83)

The following observations can be considered as being subject to or the effects of aberrant smooth muscle influence:

- Noxious somatovascular reflexes influence arteries, veins or lymphatic vascularisation. In vascular constriction, the flow of blood or lymph may compromise the delivery to associated structures of nutrients, oxygen, neurotransmitters and other humoral elements - as well as the removal of cellular waste products through venous return. There is also neural influence of the endothelial cells of the tunica intima, particularly in the microcirculation of capillaries where there is no tunica media layer of smooth muscle. As recently as 2018, Wang and Yang acknowledge that 'the pathophysiologic mechanisms leading to coronary artery vasospasms are yet completely understood.' It could be suggested that an activated noxious vertebrogenic somatocardiac reflex may be a contributory factor in some cases of arterial spasms. (18, 84, 85, 86, 87, 88, 89)
- Given that smooth muscle is innervated throughout the body including the brain, its dysfunction from noxious somato-autonomic activation may have the potential to influence physiological functions of target structures. (36, 90, 91,92, 93, 94)

In recognising a somatosensory influence on physiology Sato et al state:

> '*In contrast to the impressive body of knowledge concerning the effects of visceral afferent activity on autonomic functions, there is, generally speaking, much less information available on the reflex regulation of visceral organs by somatic afferent activity from skin, the skeletal muscle and their tendons, and from joints and other*

*deep tissues. The elucidation of the neural mechanisms of somatically induced autonomic reflex responses, usually called somato-autonomic reflexes, is, however, essential to developing a truly scientific understanding of the mechanisms underlying most forms of physical therapy, including spinal manipulation, and traditional as well as modern forms of acupuncture and moxibustion.'*(Emphasis added) (95)

Vascular headaches would appear to be a condition which is consistent with this pathophysiology model with some having been designated as cervicogenic headaches. (38, 39, 96, 97, 98, 99, 100, 101, 102, 103, 104)

This neural dysfunction model may also be a factor in vasomotor rhinitis. The exact cause of nonallergic rhinitis is idiopathic, however it is known that nonallergic rhinitis occurs when blood vessels in the nose expand and fill the nasal lining with blood and fluid. There are several possible causes, including the nerve endings in the nose being hyper-responsive, similar to the way the lungs react in asthma. (105, 106, 107, 108, 109)

Other vasomotor factors relating to dysfunction of structures that may be considered under neural overlay as visceral pathophysiology include" (32, 110, 111, 112, 113, 114)

- Within this extensive vascular network, the walls of larger individual blood and lymph vessels and nerves, are further integrated through their own networks (vasa vasorum and vasa nervorum). As well as their own individual nerve supplies, larger nerves incorporate their own filaments – the nervi nervorum. As such, noxious sensory activation may disrupt smooth muscle tone within these structures. (115, 116, 117, 118, 119, 120)
- Noxious activation of smooth muscles may inhibit peristalsis of the hollow organs such as the gastrointestinal tract including sphincters. Dyspepsia, gastric reflux, constipation and dysphagia may be symptoms of visceral dysfunction associated in such visceral pathophysiology. (121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 140, 142, 143, 144, 145)
- Urinary dysfunction may involve smooth muscle structures involving the bladder wall, sphincter or urinary ducts. (146, 147, 148, 149) There are over 40 papers on the functional conditional of enuresis listed on the *Index to Chiropractic Literature.*
- Respiration is also dependent on optimal smooth muscle function. (150, 151, 152, 153, 154, 155)
- Coronary artery smooth muscle cells appear to have slightly different properties particularly in respect of vascular repair compared to non-coronary smooth muscle cells. (23,49,84,156) In further autonomic research, Grimm and colleagues also found somatovascular responses involving the vasomotor sympathetic neurons and cardiovascular modulation in a controlled study of acute injury subjects. (157)

Tongue tie syndrome appears to be another cervicogenic disorder involving smooth muscle, one in which chiropractic manipulative care appears to attain positive outcomes. (158, 159, `60, 161, 162, 163, 164)

- Referred to as intrinsic and extrinsic factors, these terms include the ANS as well as biochemical neurotransmitters. They integrate to act as vasoconstrictors, vasodilators, and as endothelial vasomediators. Walsh notes that vascular dynamics are not solely controlled neurologically and that biochemical regulators including calcium ions, nitric oxide, angiotensin, bradykinin, serotonin, protein kinases, and others, humoral factors also influence smooth muscle function. (165, 166, 167, 168, 169, 170)

In 1980, Wickes concluded that activation of spinal segments could be associated with somatovascular reflexes. Thoracolumbar spinal manipulation appears to induce a mild segmental

somatosympathetic reflex with resultant vasoconstriction in the lower extremity vascular bed. (171)

## Somatovascular

Vascular disturbance due to smooth muscle contraction initiated by noxious activation of somatosensory and somatovascular reflexes may present as pathophysiological symptoms of homeostatic changes. (172, 173, 174, 175, 176, 177, 178, 179, 180)

This aberrant somato-autonomic reflex stimulation of the contractile property of smooth muscle underlines its potential for a localised or segmental ischemic effect on target structures with possible changes to that structure's function. The neuropathophysiology of persistent smooth muscle occlusion (or dilation) resulting in altered neurological tone, may disrupt physiological integrity of that target structure. (181, 182, 183, 184, 185)

Kurosawa noted that in rats, mechanical cutaneous stimulation can affect the adrenals and noted '*These findings suggest that; the secretion of adrenal medullary hormones can be controlled reflexly by mechanical cutaneous stimulation through CNS via adrenal sympathetic efferent nerves.*' A somatovascular reflex phenomena is a noted physiological response.(186, 186, 188, 189, 190, 191, 192, 193)

Schmorl and Junghanns noted a range of conditions associated with both spondylogenic visceral and spondylogenic vascular disturbances in their in their highly referenced chapter on Inefficient Motor Segment (Intervertebral Insufficiency). (194)

In addition Hadley noted that among other symptoms associated with a cervical syndrome, patients may experience diminished hearing as well as vasomotor disturbances. (195)

Cervicogenic factors were also noted in a study of venous perfusion by Gongal'ski and Prokopovich in 2005. Their study revealed a reflex influence on the tone of cerebral veins by proprioceptors of '*cervical spine articular complexes*'. (36)

## Angiosomes

In a similar way that the body has neural based myotomes and dermatomes, it also has angiosomes. Angiosomes relate to a three-dimensional segmental vascular distribution of the skin and underlying muscles tendons and nerves. (196) With the possible exception in plastic surgery and dermatology, this latter somite 'zoning' of vascular territories, does not seem to have attracted the same degree of attention in the way that dermatomes or myotomes have. (197, 198, 199)

Although the concept was introduced in the year 2000, as recently as 2012 the recognition of angiosomes was still regarded as a theory. Since that time it has become more widely recognised, particularly in relation to the abdominal and thoracic walls, as well as the extremities. (200, 206) Brodmann states that the body is divided up into 40 angiosomes and encompasses skin, subcutaneous tissue, fascia, muscle, and bone, while Houseman et al include specialised organs, and glands. (207)

Matthew and Hausman explain that '*The concept of the angiosome was initially described in the cutaneous blood supply, but has subsequently been shown to extend to the underlying viscera and skeleton.*' They state further that '*Devascularization of these deeper structures is less obvious than skin necrosis, but is known to occur*' particularly in '*three-dimensional vascular anatomy of the forearm and wrist.*' (208)

## Vascular tone

The integration of the autonomic nervous system with the vascular is reflected in the basic tone of blood vessels. Klabunde states that '*Vascular tone refers to the degree of constriction*

*experienced by a blood vessel relative to its maximally dilated state. All arterial and venous vessels under basal conditions exhibit some degree of smooth muscle contraction that determines the diameter, and hence tone, of the vessel…Vascular tone at any given time is determined by the balance of competing vasoconstrictor and vasodilator influences*.' (209) Intrinsic factors which can influence vascular tone include endothelial factors, local hormones, and metabolic by-products, while extrinsic neurohumoral factors include angiotensin, sympathetic neural input as well as a range of metabolites and electrolytes such a potassium. (210, 211)

Autonomic tone consists of both sympathetic and parasympathetic physiological stimulation on a wide variety of structures. (212) Autonomic tone has been suggested as a physiological form of sustained neural and vasomotor tone. This continuous neural regulation of afferent and efferent tone influences regeneration of the body's resources and contributes to the overall balance of physiological functions - homeostasis. Noxious stimulation of this physiological tone by irritant somatic sensory input essentially results in aberrant SAV reflexes and has been shown to influence the function of target organs. (12, 17, 213, 214, 215)

The endothelial layer (tunica intima) also plays a role in vascular tone by regulating factors such as transmitters, hormones and platelet substances. (216, 217) Over 30 years ago, Burnstock stated that some '*sixteen putative neurotransmitters* [had] *been identified in autonomic nerves in the past few years, including various monoamines, polypeptides, purines and amino acids*.' (56) As humoral constituents, their transport mode is dependent on optimal circulation and control of smooth muscle. (57)

Recognition is acknowledged on the importance of skeletal muscle tone and their spinal afferent association. In 1980, Newman noted that its function *'remains of great practical importance to the neurologist, since alteration in the tone of skeletal muscle is a common result of pathological processes in human diseases.*' (218)

Clinically, the effects of neural tone can be monitored relatively easily via cardiovascular changes and skin temperature differentials. Vainer suggested that changes in surface temperature symmetry '*may serve as an indicator of homeostasis*.' (219) In 2009, Manabe and colleagues developed another method of evaluating the autonomic nervous system through use of a non-invasive Doppler sonography measuring fingertip blood flow. (220) Some other methods of monitoring perfusion can involve heart rate variability, arterial blood pressure, photoplethysmography and electromyography. (221, 222, 223)

As with neural tone, (12, 14) and vascular tone (15, 211) is a homeostatic process under autonomic neural control. With such integration, somatosensory disturbance may have the potential to disrupt circulatory physiology to involved structures and consequently the function of an associated structure. (224)

## Vasomotor

Vasomotor tone is a key neurophysiological function regulating arterial blood pressure. (225) It is controlled by the respiratory centre in the medulla oblongata and subsequently by the sympathetic branch of the autonomic nervous system. (226) As vascular smooth muscle is distributed virtually throughout the neuromuscular and visceral systems, its homeostatic role is significant. Disturbance of neural tone as activated by somatovascular neural reflexes may have the potential to influence the function of structures supplied by those reflexes. (9, 11, 59, 63)

Senzon has outlined the awareness of the chiropractic model of modification to vasomotor control through neural reflex mechanisms, tonal adaptability to stimuli, and influence on neural impulses. (13, 227, 228)

## Capillaries

It is noted that there are three types of capillaries (continuous, fenestrated, and sinusoidal). Capillaries do not have a tunica media, but as microcirculation, their control of circulation called vasomotion, is influenced by chemical signals. Arterioles do have a tunica media while metarterioles and precapillary sphincters have circular smooth muscle. Histologically, venules are similar to arterioles, but with much thinner layers in the vessel walls. (229, 230)

Mechanoreceptors in muscles involved in the vertebral subluxation complex (VSC) may affect pressor reflexes and be reflected in capillary and cardiovascular circulation. It is submitted that hypertonic muscles associated with spinal segmental mechanical fixations may lead to somatosensory reflex activation and result in vasopressor ischemia and/or a somatopressor response in the microcirculation. This may well classify the subluxation as more of a complex rather than just a mechanical disturbance. (52, 53, 64, 231, 232, 233, 234, 235, 236)

## Inflammation

Kirillova-Woytke and colleagues demonstrated a distinct somatovascular link through nociceptive activated spinal circuits, particularly in the presence of inflammation, namely an inhibition of vasoconstriction with an increased blood flow to provide immunocompetent cells, proteins, and oxygen They state that '*the nociceptive afferents were excited by mechanical somatic stimulation, albeit of the toes in this research using rat subjects.*' (237, 238)

## Vascular dysfunction

While terms such as smooth muscle dysfunction, autonomic dysfunction and vascular dysfunction are becoming more common as diagnostic terms, the mechanism behind the dysfunction concept may at times prove to be at least partly if not predominantly a somato-autonomic link. (102, 239)

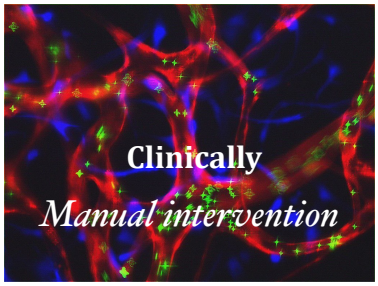
The literature contains many references to vascular dysfunction. (51, 71, 240) One cause is attributed to a vessel's response in vascular migraine. (241) However van der Velde and de Boer also suggest that vessel wall endothelial dysfunction may precede hypertension. (242)

It is suggested here that a somatic sensory factor in the form of a noxious somato-autonomic reflex may have the potential to be one of the forms of such a somatovascular dysfunction. A primary source of such sensory reflexes is the spine - mechanically disturbed vertebrae or other somatic structure may be a reasonably common form of such dysfunction from the somatosensory aberrations. (243) Vascular dysfunction may also involve the lymphatic vessels. (62, 244)

A 2018 study by Sheng and Zhu notes the critical role of the ANS in the regulation of vascular wall contractility and tension. In potential supporting evidence of the concepts discussed in this paper, they state further that dysfunction of the ANS system could be a risk factor for vascular diseases and the overactive sympathetic nervous system is detrimental to the blood vessels. (51)

## Thermography

The warmth of distal extremities can reflect the intensity of the blood flow (haemodynamics) to that extremity, particularly arterioles and capillaries. Capillaries carry some 5% of the total blood volume so that slight changes in temperature differentials may be monitored. Two emerging technologies for this utilise biological thermocouple sensory scans and infrared photo imagery. Both are reliant on those temperature differentials which may also be based on somatovascular reflexes through the effect on smooth muscle. Paraspinal temperature differentials may also be monitored as a means of assessing autonomic tone at a segmental level. (69, 224, 245, 246, 247, 248, 249, 250)




The intention of this discourse in particular is to explore potential influence of neurogenic lowering of vascular blood flow on tissue at a focal level. That is, the possibility of vascular constrictions associated with sympathetic somatosensory reflex activation. Sato et al suggest vascular function may be influenced by an axonal reflex following noxious somatic afferent stimulation. (50, 85, 116, 117, 122, 127, 136, 141, 145 193, 194, 195, 235, 251)

The significance of perceived smooth muscle innervation takes on further importance when one considers that virtually all biological structures have dual innervation - a direct parasympathetic and sympathetic autonomic supply, but also a somewhat indirect one through the *vasa nervorum*. (115, 116, 118, 120,2 52)

A case-controlled study of cases with peripheral artery disease found that the affected region experienced significantly improved circulation following osteopathic manipulation. While Lombardini et al found that osteopathic manipulation improved endothelial function and other vascular symptoms. (193)

Vaňásková and colleagues note a somato-autonomic smooth muscle association with viscera. They stated '*It would seem justifiable to assume that lesion in a motion segment of the spinal column may impair function in the corresponding internal organs. This is borne out by the vasomotor response in the whole segment to which pain is referred. In such cases we can see the disorder clearing up as soon as we treat the motion segment.*' (141)

A further study by Karason and Drysdale found that a high velocity low amplitude (HVLA ) osteopathic lumbosacral manipulation produced a '*significant increase in cutaneous blood flow over the L5 dermatome*' bilaterally in non-smokers. Interestingly, smokers responded with a decrease in blood flow bilaterally. They also note a visceral response is associated with this procedure. (192)

In further recognition of a spinal somatovascular association, a number of European medical authors have reported a vertebrogenic and somato-autonomic association with circulation including vasomotor disorders, and plethysmographic studies. (31, 32, 33, 34, 35, 36)

## Conclusion

Smooth muscle dissemination is extensive throughout the body and is subject to the influence of the ANS. Further, the ANS responds to somatosensory activation. It is then reasonable to conclude that segmental noxious somato-autonomic reflex activity would have the potential to influence ischemic sites involving particular organs or parts of organs. As such, addressing the aberrant SAV reflexes may play a role in alleviating some internal dysfunctions and symptoms by stabilising neural control, and subsequently normalising or modifying the altered blood supply.

The autonomic nervous system can influence the circulatory dilation and constriction through its effect on the smooth muscle layer in the walls of blood vessels. Input from somatosensory/ somatovascular reflexes may influence those vascular properties. Thus the normalising of noxious sensory input may positively influence circulatory changes and the function of the associated organs supplied by the involved vascular subdivision(s) or angiosome.

The evidence suggests that somatovascular interaction of smooth muscle with somato-autonomic reflexes may be positively influenced by corrective vertebral adjustments of segmental subluxations. This intervention would be directed towards ameliorating noxious somatic reflexes affecting pathophysiological functional disorders and related symptoms of this somatovascular

association. The existence of angiosomes may also indicate the necessity for specificity of such vertebral adjustments.

It is hypothesised that under chronic vasoconstriction, further research may ultimately demonstrate a tendency for some predisposed tissues to be subject to developing symptoms and possibly visceral dysfunction.

The chiropractic, osteopathic and medical evidence produced in this review tends to support the chiropractic subluxation model as a factor in some dysfunctional visceral conditions. It is noted that there is a dearth of evidence to the contrary, yet anecdotally these changes have been observed by practitioners over many years. It is hoped that this paper will demonstrate the link between these observations and the possible source of the changes noted, and that it will serve to establish that SMT is not merely a musculoskeletal therapy but has a far greater influence with regards to the restoration of function on many levels.

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## References

1. Hafen BB, Shook M, Burns B. Anatomy, smooth muscle. StatPerls. 2020, https://www.ncbi.nlm.nih.gov/books/NBK532857/
2. Biga LM, Dawson S, Harwell, A, et al. Smooth muscle tissue. Anatomy & Physiology. https://open.oregonstate.education/aandp/chapter/10-7-smooth-muscle-tissue/
3. Hornyak M, Naver HK, Rydenhag B, Wallin GB. Sympathetic activity influences the vascular axon reflex in skin. Acta Physiologica Scand 1990;139(1):77-84
4. Pickar J. Neurophysiological effects of spinal manipulation. Spine J. 2002;2(5):357-71
5. Gyer G, Michael J, Inklebarger J, Tedla JS. Spinal manipulation therapy: is it all about the brain? A current review of neurophysiological effects of manipulation. J Integr Med. 2019;17:328-37
6. Research Library. Primary Spine and Rehab. https://primaryspinerehab.com/Neurophysiological-Effects.htm
7. Wirth B, Gassner AM, de Bruin E, et al. Neurophysiological effects of high velocity and low amplitude spinal manipulation in symptomatic and asymptomatic humans. Spine. 2019;44(15):E914-E926
8. Senzon S. Viscero-cutaneo-vascular reflex and its clinical significance. (Appendix VIII). The Institute Chiropractic - Senzon Learning, Inc. (Extract from: Ishikawa T. Segmental neuropathy – The first evidence of developing pathology. https://www.institutechiro.com/waves/1928-1975/sixth-wave-chiropractic/segmental-neuropathy/viscero-cutaneo-vascular-reflex-tachio-ishikawa/. 2020
9. Homeostatic regulation of the vascular system - Neural regulation. In: Cardiovascular system: blood vessels and circulation. Rice University. 2019 https://opentextbc.ca/anatomyandphysiology/chapter/20-4-homeostatic-regulation-of-the-vascular-system/
10. Hall MW, Jensen AM, The role of pulse oximetry in chiropractic practice: a rationale for its use. J Chiropr Med. 2012;11(2):127-33
11. Modell H, Cliff W, Michael J, et al. A physiologist's view of homeostasis. Adv Physiol Educ. 2015;38(4):259-66
12. McDowall D, Emmanuel E, Grace S, Chaseling M. Tone as a health concept. Complement Ther Clin Prac. 2017;29:27-34
13. Cauwenberg P. Vertebral subluxation and the autonomic nervous system. In: Gatterman M. Foundations of chiropractic subluxation. St Louis: Elsevier Mosby. 2005;305-36

14. Eingorn AM, Muhs GJ. Rationale for assessing the effects of manipulative therapy on autonomic tone by analysis of heart rate variability. J Manipulative Physiol Ther. 1999;22(3):161-5
15. Walsh MP. Regulation of vascular smooth muscle tone. Can J Physiol Pharmacol. 1994;72(8):919-36
16. Burnstock G, Holman ME. Smooth muscle: autonomic nerve transmission. Ann Rev Physiol 1963;25:61-90
17. Autonomic tone. In: Autonomic Nervous System. CNS Clinic Jordan. http://www.humanneurophysiology.com/autonomicns.htm. Extracted Nov 6, 2018
18. Sato A, Sato Y, Schmidt RF. Somatosensory modulation of the cardiovascular system. In: The impact of somatosensory input on autonomic functions. Reviews of Physiology, Biochemistry and Pharmacology. Berlin: Springer-Verlag, 1997;130:115-144
19. Khayutin VM, Lukoshkova EV. Spinal mediation of vasomotor reflexes in animals with intact brain studied by electrophysiological methods. Pflügers Archiv. 1970;321:197-222
20. Welch A, Boone R. Sympathetic and parasympathetic responses to specific diversified adjustments to chiropractic vertebral subluxations of the cervical spine. J Chiropr Med 2008;7(3):86-93
21. Budgell BS. Reflex effects of subluxation: the autonomic nervous system. J Manipulative Physiol Ther 2000;23(2):104-6
22. Wernöe TB. Viscero-cutaneous anaemic zones and their significance. J Neurol Psychopathol 1923;4(14):103-24
23. Adams-Ray J. Studies on a cutaneous pallor reflex in the fourth cervical segment in cardiac pain. Acta Medica Scand 1953;146(6):457-72 https://onlinelibrary.wiley.com/doi/abs/10.1111/j.0954-6820.1953.tb10259.x
24. Adams-Ray J., Norlen G. Bladder distension reflex with vasoconstriction in cutaneous venous capillaries. Acta Physiol Scand, 1951;23(2-3):95-109 https://onlinelibrary.wiley.com/doi/abs/10.1111/j.0954-6820.1953.tb10259.x
25. Adams-Ray J. Photometrical studies on viscerocutaneous reflexes with vasoconstriction in venous capillaries (Wernöe's symptom) in gall-bladder disease. Angiol 1951;2(1):51-9
26. Kiyomi K. Autonomic system reactions caused by excitation of somatic afferents: Study of cutaneo-intestinal reflex. In: Korr IM (ed), The neurobiologic mechanism in manipulative therapy. New York: Plenum; 1978, pp 219-227
27. Wright HM, Korr IM, Thomas PE. Local and regional variations in cutaneous vasomotor tone of the human trunk. Acta Neuroveg 1960;22(1-2):33-52
28. Vicenzino B, Collins D, Wright T. Sudomotor changes induced by neural mobilisation technique in asymptomatic patients. J Man Manip Ther. 1994;2(4):66-74
29. Korr IM, Wright HM, Grace JR. Cutaneous patterns of sympathetic activity in clinical abnormalities of the musculoskeletal system. J Neural Transmission 1964;25:589-606.
30. Korr IM. The neural basis of the osteopathic lesion. J Am Osteopath Assoc 1947;47(4):191-198. http://www.ipoc.pt/wp-content/uploads/2016/11/The-Neural-Basis-of-the-Osteopathic-Lesion_eng.pdf
31. Figar S, Krausova L. A plethysmographic study of the effects of chiropractic treatment in vertebrogenic syndromes. Acta Universitatis Carolinae (Med) Suppl 1965;21:84-86.(Also in Cesk Neurol. 1964;27:246-250. (Czech)
32. Figar S, Stary O, Hladka V. Changes in vasomotor reflexes in painful vertebrogenic syndromes. Rev Czech Med. 1964;10:238-246 (Also in Cesk Neurol. 1963;26:353-360. Czech. (Pubmed extract)
33. Figar S, Krausova L, Lewit K. [Plethysmographic investigations in the chirotherapy of vertebral disorders.] Acta Neuroveg (Wein) 1967;29(4):618-623. (German) (PMID 6082265 Pubmed)
34. Stary O, Figar S, Andelova E, Hladka V, Jansky m, Kalvodova e. [Analysis of disorders of vasomotor reactions in lumbosacral syndromes.] Cesk Neurol. 1964;27:214-218. Czech. (Pubmed extract)
35. Stary O, Figar s. [Mediator and higher nervous reflex mechanisms of the vasomotor reactivity in painful vertebrogenic syndromes.] Cesk Neurol. 1965;28:213-219. (Czech)(Pubmed extract)
36. Gongal'skiĭ V V, Kuftyreva TP. [Vascular and autonomic disorders of the spinal cord in dystopia of the spinal motor segment] Neirofiziologiia. 1992;24(6):667-72. [Article in Russian] [English abstract]
37. Ogura T, Tashiro M, Masud M, et al. Cerebral metabolic changes in men after chiropractic spinal manipulation for neck pain. Altern Ther Health Med. 2011;17(6):12-17
38. Vernon H, Dhami MSI. Vertebrogenic migraine. J Can Chiropr Assoc. 1985;29(1):20-24
39. Vernon H. The effectiveness of chiropractic manipulation in the treatment of headache: an exploration in the literature. J Manipulative Physiol Ther. 1995;18(9):611-17
40. Senzon SA, The chiropractic vertebral subluxation Part 7: Technics and models from 1962 to 1980. J Chiropr Humanit 2018;25C:99-113
41. Senzon SA, The chiropractic vertebral subluxation Part 9: Complexes, models, and consensus from 1979 to 1995. J Chiropr Humanit 2018;25C:130-145
42. Senzon SA, The chiropractic vertebral subluxation Part 10: Integrative and critical literature from 1996 and 1997. J Chiropr Humanit 2018;25C:146-168

43. Senzon S. Thermal gradient – dilation. The Institute Chiropractic - Senzon Learning, Inc. https://www.institutechiro.com/waves/1928-1975/sixth-wave-chiropractic/segmental-neuropathy/thermal-gradient/, 2020
44. Senzon S. Vascular innervation – dilatation. In: Segmental neuropathy, the fist evidence of developing pathology. 2nd edn. The Institute Chiropractic. Senzon Learning. https://www.institutechiro.com/waves/1928-1975/sixth-wave-chiropractic/segmental-neuropathy/vascular-innervation-dilatation/ 2014
45. Grgić V. [Cervicogenic dysphagia: swallowing difficulties caused by functional and organic disorders of the cervical spine.] Lijec Vjesn. 2013;135(3-4):92-99.{Croatian, English abstract)
46. Mathias CJ. Bannister R. Autonomic failure: a textbook of clinical disorders of the autonomic nervous system. 5th edn. Oxford. Oxford University Press. 2013:805
47. Wecht JM, Bauman WA. Implication of altered autonomic control for orthostatic tolerance in SCI. Auton Neurosci. 2018;209:51-58. doi: 10.1016/j.autneu.2017.04.004
48. Sato A, Sato Y, Schmidt RF. Somatosensory modulation of blood flow. The impact of somatosensory input on autonomic functions. In: Reviews of Physiology Biochemistry and Pharmacology. Ed. Blaustein MP et al.] Berlin: Springer-Verlag. 1997;130:148-66
49. Sato A, Sato Y, Schmidt RF. Somatosensory modulation of the cardiovascular system. In: The impact of somatosensory input on autonomic functions. Reviews of Physiology Biochemistry and Pharmacology. Ed. Blaustein MP et al.] Berlin: Springer-Verlag. 1997;130: 115-166
50. Sato A, Budgell B. The cervical subluxation and regional blood flow. J Manipulative Physiol Ther 1997;20(2):103-7
51. Sheng Y, Zhu L. The crosstalk between autonomic nervous system and blood vessels. Int J Physiol Pathophysiol Pharmacol 2018;10(1):17-28
52. Amiya E, Watanabe M, Komuro I. The relationship between vascular function and the autonomic nervous system. Ann Vasc Dis 2014;7:109-119
53. Nutter, D.O., and Wickliffe, C.W. Regional vasomotor responses to the somatopressor reflex from muscle. Circ. Res. 1981;48(Suppl. 1):98–103
54. Figar S. [Changes in vasomotor reflexes in painful vertebrogenic syndromes.] Rev Czek Med. 1964;10(4):238-246
55. Canning BJ. Reflex regulation of airway smooth muscle tone. Respir Physiol. 2001;125(1-2):113-127
56. Burnstock G. Nervous control of smooth muscle by transmitters, cotransmitters and modulators. Experientia 1985;41(7):869-874
57. Burnstock G. Autonomic neuroeffector mechanisms in smooth muscle. Nihon Heikatsukin Gakkai Zasshi 1984;20(5):365-392 (Abstract)
58. Burnstock G. Non-synaptic transmission at autonomic neuroeffector junctions. Neurochem Int 2008;52(1-2):14-25
59. Jänig W. Integration of neural and non-neural signals influencing blood vessels. In: The integrative action of the autonomic nervous system. Neurobiology and homeostasis. Cambridge: Cambridge Press. 2006:273-276
60. Yamaguchi S, Ito M, Ohshima N. Somatosensory nociceptive mechanical stimulation modulates systemic and mesenteric microvascular hemodynamics in anesthetised rats. Autonom Neurosci. 2001;88(3):160-6
61. Bengochea K. Smooth musculature. https://www.kenhub.com/en/library/anatomy/smooth-musculature
62. von der Weid P-Y, Zawieja DC. Lymphatic smooth muscle: the motor unit of lymph drainage. Int J Biochem Cell Biol. 2004;36(7):1147-53
63. Jänig W. Sympathetic vasoconstrictor pathways. In: The integrative action of the autonomic nervous system. Neurobiology and homeostasis. Cambridge: Cambridge Press. 2006:107-141
64. Chai CY, Wu WC, Wang S, et al. Coexistence of autonomic and somatic mechanisms in the pressor areas of medulla in cats. Brain Res Bull 1992;29(1):15-26
65. Budgell BS, Sato A, Suzuki A. Responses of adrenal function to stimulation of lumbar and thoracic interspinous tissues in the rat. Neurosci Res 1997;28:33-40
66. Banerjee D. Endothelial cell and vascular smooth muscle cell dysfunction in chronic kidney disease. Internat J Cardiol 2018;254:297-298
67. Poblet E, Orega F, Jiménez F. The erector pili muscle and the follicular unit of the scalp: a microscopic anatomy study. Dermatol Surg 2002;28(9):800-803
68. Jänig W. Autonomic nervous system. In: Schmidt R.F., Thews G. (eds) Human Physiology. Springer, Berlin, Heidelberg. 1989. https://doi.org/10.1007/978-3-642-73831-9_16
69. Scallan JP, Zawieja SD, Castorena-Gonzalez JA, Davis MJ. Lymphatic pumping: mechanics, mechanisms and malfunction. J Physiol 2016;594(20):5749-5768
70. Sorenson RL, Breije TC. Atlas of human histology. Histology Guide http://www.histologyguide.com/index.html
71. Hillman EM, Devor A, Bouchard M, et al. Depth-resolved optical imaging and microscopy of vascular compartment dynamics during somatosensory stimulation. Neuroimage 2007;35(1):89-104

72. Jänig W. Autonomic reflexes. In: Binder M.D., Hirokawa N., Windhorst U. (eds) Encyclopaedia of Neuroscience. Springer, Berlin, Heidelberg. 2008. https://doi.org/10.1007/978-3-540-29678-2_487
73. Cui K, Li W, Liu X, Li N, Wu G. Effect of cervical manipulation on autonomic nerve function in healthy volunteers. J Acupuncture Tuina Scienc. 2006;4(5):267-70.
74. Sato A, Sato Y, Schmidt RF. (18) p 7
75. O'Herron P, Chhatbar PY, Levy M, et al. Neural correlates of single-vessel haemodynamic responses in vivo. Nature. 2016;534(7607):378-82
76. Jänig W. Functions of the autonomic nervous system: current concepts. In King HH, Jänig W, Patterson MM. The science and clinical application of manual therapy. Edinburgh: Churchill Livingston. 2011;15-53
77. Gavornik P, Dukát A, Gašpar L, et al. Mesenterointestinocolonovascular arterial ischemic disease: guidelines of the angiology section of Slovak Medical Chamber (AS SMC, 2013)] Vnitr Lek 2014;60(3):239-248 (Abstract only)
78. Calkasiński I, Dobrzyński M, Haloń A, et al. [Humoral-circulatory response in the somato-vegetative reflex caused by pain factors]. Postepy Hig Med Dosw. 2007;61:331-337 (Abstract)
79. Klabunde RE. Cardiovascular physiology concepts. 2014. https://www.cvphysiology.com/Blood%20Flow/BF002
80. Navar LG. Physiology: hemodynamics, endothelial function, renin-angiotensin-aldosterone system, sympathetic nervous system. J Am Soc Hypertens. 2014;8:519-524
81. Ahmed TA, El-Badri N. Pericytes: the role of multipotent stem cells in vascular maintenance and regenerative medicine. Adv Exp Med Biol 2018;1079:69-86
82. Bergers G, Song S. The role of pericytes in blood-vessel formation and maintenance. Neuro Oncol. 2005;7(4):452-464
83. Diaz-Flores L, Gutiérrez R, Madrid JF, et al. Pericytes, morphofunction, interactions and pathology in a quiescent and activated mesenchymal cell miche. Histol Histpathol 2009;24(7):909-969
84. Wang SS, Yang EH. What is the pathophysiology of coronary artery vasospasm? Medscape. 2018; https://www.medscape.com/answers/153943-103024/what-is-the-pathophysiology-of-coronary-artery-vasospasm
85. Budgell BS, Sato A. Somatoautonomic reflex regulation of sciatic nerve blood flow. J Neuromuscular Syst 1994;2:170-177
86. Goodman JR, Iliff JJ. Vasomotor influences on glymphatic-lymphatic coupling and solute trafficking in the central nervous system. J Cereb Blood Metab. 2020;40(8):1724-1734
87. Chakraborty S, David MJ, Muthuchamy M. Emerging trends in the pathophysiology of lymphatic contractile function. Sem Cell Develop Biology. 2015;38:55-66.
88. Kokjohn K. Schmid DM, Triano JJ, Brennan PC. The effect of spinal manipulation on pain and prostaglandin levels in women with primary dysmenorrhea. J Manipulative Physiol Ther 1992;15(5):279-285
89. Degenhardt BF, Kuchera ML. Update on osteopathic medical concepts and the lymphatic system. J Am Osteop Assoc 1996;96(2):97-100
90. Jänig W. The integrative action of the autonomic nervous system. Neurobiology of homeostasis. Cambridge: Cambridge University Press. 2006
91. Budgell BS. Modulation of visceral function by somatic stimulation. In : King HH, Jänig W, Patterson MM. The science and clinical application of manual therapy. Edinburgh: Churchill Livingstone.2011;71-83
92. Itoh H, Sakai J, Imoto A, Creed KE. [The control of smooth muscle tissue by nonadrenergic noncholinergic (NANC) nerve fibres in the autonomic nervous system]. J Smooth Muscle Res 1995;31(3);67-78. [Japanese, English abstract]
93. Kuriyama H, Kilamura K, Itoh T, Inoue R. Physiological features of visceral smooth muscle cells, with special reference to receptors and ion channels. Physiol Rev 1998;78(3):811-920
94. Alberts B, Johnson A, Lewis J, et al. Molecular Biology of the Cell. 4th edition. New York: Garland Science; 2002. Blood Vessels and Endothelial Cells. Available from: https://www.ncbi.nlm.nih.gov/books/NBK26848/
95. Sato A, Sato Y, Schmidt RF. (18) p1-2
96. Bogduk N. The anatomical basis for cervicogenic headache. J Manipulative Physiol Ther 1992;15(1):67-70
97. Bogduk N. Cervicogenic headache: anatomic basis and pathophysiologic mechanisms. Curr Pain Headache Rep 2001;5(4):382-386
98. Chaibi A, Tuchin PJ. Chiropractic spinal manipulative treatment of cervicogenic dizziness using Gonstead method: a case study [case report]. J Chiropr Med 2011;10(3):194-198
99. Sjaastad O, Fredriksen TA, Stolt-Nielsen A. Cervicogenic headache, C2 rhizopathy, and occipital neuralgia: a connection? Cephalalgia 1986;6(4):189-195
100. Alix ME, Bates DK. A proposed etiology of cervicogenic headache: the neurophysiologic basis and anatomic relationship between dura mater and rectus posterior capitis minor muscle. J Manipulative Physiol Ther 1999;22(8):534-539
101. Dalkara T, Nozari A, Moskowitz MA. Migraine aura pathophysiology: the role of blood vessels and microembolism. Lancet Neurol 2010;9(3):309-317

102. Napoli R, Guardasole V, Zarra E, et al. Vascular smooth muscle cell dysfunction in patients with migraine. Neurology 2009;72(24):2111-2114
103. Kapoor S. Headache attributed to cranial or cervical vascular disorders. Curr Pain Headache Rep. 2013;17(5):334. doi: 10.1007/s11916-013-0334-y
104. Naude C. Ischemic compression of the suboccipital muscles in conjunction with chiropractic spinal manipulative therapy on cervicogenic headache. Masters Dissertation, Department of Chiropractic. University of Johannesburg. 2015 https://ujcontent.uj.ac.za/vital/access/manager/Repository/uj:1092?f0=sm_subject%3A%22Ischaemic+compression%22
105. Debain JJ. [Otorhinolaryngologic manifestations of cervical origin.] Probl Actuels Otorhinolaryngol. 1972;257-77. PMID: 4668389 (French) (Pubmed )
106. Falkenau HA. [Chiropractic management of the cervical syndrome in oto-rhino-laryngology (Author's translation)] HNO 1977;25(8):269-272. (German) (PubMed Abstract Only)
107. Sarin S, Undem B, Sanico A, Togias A. The role of the nervous system in rhinitis. J Allergy Clinical Immunol. 2006;118(5):999-1014
108. Shan S, Graven K, Sergi M, Hostoffer R. Rhinitis: the osteopathic modular approach. J Am Osteopathic Assoc 2020;120:351-358
109. Baraniuk JN. Pathogenic mechanisms of idiopathic nonallergic rhinitis. World Allergy Organ J 2009;2(6):106-114
110. Rossmanith WG, Ruebbert W. What causes hot flushed? The neuroendocrine origin of vasomotor symptoms in the menopause. Gynecol Endocrinol 2009;25(5):202-214
111. Rapkin AJ. Vasomotor symptoms in menopause: physiologic condition and central nervous approaches to treatment. Am J Obstet Gynecol 2007;196(2):97-106
112. Wasner G. Vasomotor disturbances in Complex Regional Pain Syndrome – review. Pain Med 2010;11(8):1267-1273
113. Chapman DG, Irvin CG. Mechanisms of airway hyperresponsiveness in asthma: the past, present and yet to come. Clin Exp Allergy. 2016;45(4):706-719
114. Baroffio M, Barisione G, Crimi E, Brusasco V. Noninflammatory mechanisms of airway hyperresponsiveness in bronchial asthma: an overview. Ther Adv Respir Dis. 2009;3(4):163-74
115. Hotta H, Nishijo K, Sato A, Sato Y, Tanazawa S. Stimulation of the lumbar sympathetic trunk produces vasoconstriction of the vasa nervorum in the sciatic nerve via alpha-adrenergic receptors in rats. Neurosci Lett 1991;133:249-252
116. Boissaud-Cooke MA, Pidgeon T, Tunstall RG. The microcirculation of peripheral nerves: the vasa nervorum. In Nerves and nerve injuries. Academic Press 2015. https://doi.org/10.1016/B978-0-12-410390-0.00039-1
117. Williams JK, Heistad DD. Structure and function of vasa vasorum. Trends Cardiovasc Med 1996;6(2):53-57
118. Teixeira MJ, Almeida DB, Yeng LT. Concept of acute neuropathic pain. The role of nervi nervorum and the distinction between acute nociceptive and neuropathic pain. Revista Dor. 2016;17(S1):S5-S10
119. Sato A, Sato Y, Schmidt RF. (18) p165
120. Appenzeller O, Dhital KK, Cowen T, Burnstock G. The nerves to blood vessels supplying blood to nerves: the innervation of vase nervorum. Brain Res, 1984:304(2):383-386
121. Falkenau HA. [The pathogenesis and chiropractic management of cervical dysphagia) Author's translation.)] Laryngol Rhinol Otol (Stuttg) 1977;56(5):467-469. (German)
122. Hülse, M. (1991). Zervikale Dysfonie. [Cervical dysphonia ] Folia Phoniatrica, Vol. 43, No. 4, (1991), pp. 181-196, ISSN 0015-5705
123. Angus K, Asgharifar S, Gieberzon B. What effect does chiropractic treatment have on gastrointestinal (GI) disorders. A narrative review of the literature. J Canad Chiropr Assoc 2015;59(2):122-133
124. Budgell B, Suzuki A. Inhibition of gastric motility by noxious chemical stimulation of interspinous tissues in the rat. J Auton Nerv Syst 2000;80(3):162-168
125. Castellucci RR. Resolution of colic in an eight-week old infant undergoing chiropractic care. A case study. J Pediatr Matern Fam Health Chiropr 2012;4:109-112.
126. Deboer KF, Schutz M, McKnight ME. Acute effects of spinal manipulation on gastrointestinal myoelectric activity in conscious rabbits. Manual Med 1988;3:85–94.
127. Filippkin MA, Akberov RF, Vasenin BN. [Functional disorders of the digestive tract in children with vertebrogenic diseases] Vestn Rentgenol Radiol. 1995 Nov-Dec;(6):19-22. [Russian]. (Pubmed extract)
128. Parodi J, Grisoni E, Ferrario C, Kramer A, Beven E. Hypertonicity of intestinal smooth muscle as a factor of intestinal ischemia in necrotising enterocolitis. J Ped Med. 1987;22(8):P713-718
129. Gutzeit K. Das neurovaskulare problem in der Ätiologie und pathogenese von ulcus peptic und gastritis (enteritis).(The neurovascular problem in the etiology and pathogenesis of peptic ulcer and gastro-enteritis.) Münchener Medizinische Wochenschrift 1951;93:47-49. (Cited in Weiant CW, Goldschmidt S. Medicine and chiropractic. Self Published, New York. 1966:120.)
130. Loo M, Fitzgerald MA, Spicer A, et al. Colic. In: Loo M, (Ed) Integrative medicine for children. Chapter 23. Edinburgh: Elsevier; 2009;248-258 https://www.sciencedirect.com/science/article/pii/B9781416022992100234

131. Manabe N, Tanaka T, Hata J, Kusunoki H, Haruma K. Pathophysiology underlying irritable bowel syndrome – from the viewpoint of dysfunction of autonomic nervous system activity. J Smooth Muscle Res. 2009;45(1):15-23
132. Mathias, J. R., & Clench, M. H. Neuromuscular diseases of the gastrointestinal tract. Specific disorders that often get a nonspecific diagnosis. Postgraduate Medicine/ 1995;97(3): 95-108
133. Nansel D, Szlazak M. Somatic dysfunction and the phenomenon of visceral disease simulation. J Manipulative Physiol Ther. 1995;18(6);379-397
134. Qu LX. [Relationship between irritable bowel syndrome and unstable thoracolumbar vertebrae]. Zhongguo Gu Shang. 2009 Jun;22(6):456-7
135. Rhodes C, Bentley M, Linmk G, Fong P. Resolution of chronic dysphagia in a 73 year old female receiving chiropractic care. A case report. Ann Vert Sublux Res 2015;1:23-25
136. Rychlíková E, Lewit K. [Functional disorders of the spine and reflex changes in peptic ulcer of adolescents.] Vnitr Lek. 1976;22(4):326-335
137. Sato, Y. & Terui, N. (1976). Changes in duodenal motility produced by noxious mechanical stimulation of the skin in rats. Neuroscience Letters.1976;2(4):189-193
138. Thumshirn M. Pathophysiology of functional dyspepsia. Gut.2002;51(Suppl 1):63-66
139. Tsuchiya M, Oda M, Nakamura M, et al [Studies on the autonomic nervous regulation of the gastric mucosal microcirculation in rats – with special reference to the pathogenesis of experimental restraint-induced gastric ulcer. Nihon Shokakibyo Gakki Zasshi 1981;78(5):1000-1014
140. Tsuji S, Kawano S, Tsuji M, et al. [Mucosal microcirculation and angiogenesis in gastrointestinal tract]. Hihon Rinsho 1998;56(9):2247-2252. (Japanese)
141. Vaňásková E, Hep A, Vižďa J, Tosnerová V. Swallowing disorders related to vertebrogenic dysfunction. Ceska a Slovenska Neurologie a Neurochirurgie 2007;70(6):692-696. In: Brzozowski T (Ed.). New advances in the basic and clinical gastroenterology., ISBN: 978-953-51- 0521-3; 2012. Rijeka, Croatia; In: Tech. 2012 p175-184 http://www.intechopen.com/books/new-advances-in-the-basic-and-clinicalgastroenterology/swallowing-disorders-related-to-vertebrogenic-dysfunctions.
142. Vaňásková, E., Hep, A., Lewit, K., Tosnerova, V., Prasek, J., Vizda, J., Dite, P. & Dolina, J. (2001). Cervical dysfunction with disturbed oesophageal motility – scintigraphic assessment. J Orthopaedic Med. 200123(1): 9-11
143. Yamaguchi S, Ito M, Ohshima N. Somatosensory nociceptive mechanical stimulation modulates systemic and mesenteric microvascular hemodynamics in anesthetised rats. Auton Neurosci 2001;88(3):160-166
144. Walden AL, Salsbury SA, Reed WE, Lawrence DJ. Bladder and bowel symptoms among adults presenting with low back pain to an academic chiropractic clinic. Results of a preliminary study. J Chiropr Med 2014;13(3):178-187
145. Young MF, McCarthy PW, King SJ. Chiropractic manual intervention in chronic adult dyspepsia: a pilot study. Clin Chiropr 2009;12(1):28-34
146. Budgell BS, Hotta H, Sato A. Reflex responses of bladder motility after stimulation of interspinous tissues on the anesthetized rat. J Manipulative Physiol Ther 1998;21:593-599
147. Cooperstein R, Lisi AJ, Burd A. Manual therapy approaches to the overactive bladder: a narrative literature review. J Chiropr Med. 2014;13:81-89
148. Zhang J, Haselden P, Tepe R. A case series of \reduced urinary incontinence in elderly patients following chiropractic manipulation. J Chiropr Med. 2006;5(3):88-91
149. Riemer RK, Heymann MA. Regulation of uterine smooth muscle function during gestation. Pediatr Res. 1998;44(5):615-627
150. Bara I, Ozier A, Tunon de Lara J-M, Marthan R, Berger P. Pathophysiology of bronchial smooth muscle remodelling in asthma. Eur Resp J. 2010;36:1174-84
151. James A, Carroll N. Airway smooth muscle in health and disease; methods of measurement and related function. Eur Resp J. 2000;15(4):782-9
152. Mitzner W. Airway smooth muscle the appendix of the lung. Am J Resp Crit Care Med. 2003;169(7):787-90.
153. Bisconti AV, Devoto M, Venturelli M, et al. Respiratory muscle training positively affects vasomotor response in young healthy women. PLoS One. 2018 Sep 25;13(9):e0203347. doi: 10.1371/journal.pone.0203347
154. Lo CCW, Moosavi SM, Bubb KJ, The regulation of pulmonary vascular tone by neuropeptides and the implications for pulmonary hypertension. Front Physiol. 2018;9:1167.doi: 3389/fphys.2018.01167
155. Lucks C, Lucks L. Improvement of a functional movement disorder in a patient receiving Network Spinal analysis and somato respiratory integration care. A case report. Ann Very Sublux Res 2015;2:24-33
156. Patel S, Shi Y, Niculescu R, et al. Characteristics of coronary smooth muscle cells and adventitial fibroblasts. Circulation. 2000;101:524-32
157. Borody C. Neck-tongue syndrome. J Manipulative Physiol Ther. 2004;27(5):357. e8.

158. Grimm DR, Cunningham BM, Burke JR. Autonomic nervous system function among individuals with acute musculoskeletal injury. J Manipulative Physiol Ther. 2005;28(1):44-51
159. Buroon M, Pero J. Resolution of glossopharyngeal neuralgia & spastic dystonia following chiropractic care to reduce upper cervical vertebral subluxation: A case study [case report]. J Upper Cervical Chiropr Res. 2014:1:7-13
160. Hankey, GJ. Neck-tongue syndrome on sudden neck rotation. Aust N Z J Med. 1988; 18:181
161. Hubbard MA. Paediatric cholelithiasis and breastfeeding difficulties: A chiropractic case report [case report]. J Clin Chiropr Pediatr. 2014;14(2):1144-1150
162. Lavigne V. A narrative review and case report. Frenotomy procedure in neonate with tongue-tie. J Clin Chiropr Pediatr. 2012;13(2):1025-1031
163. Lois I. The cervicolingual syndrome. Man Med. 1987; 3: 63–66
164. Terrett, AGJ. Neck-tongue syndrome and spinal manipulative therapy. In: H Vernon (Ed.) Upper cervical syndrome: chiropractic diagnosis and treatment. Williams & Wilkins, Baltimore; 1988: 223-229
165. Brozovich FV, Nicholson CJ, Degen CV, et al. Mechanisms of vascular smooth muscle contraction and the basis for pharmacological treatment of smooth muscle disorders. Pharmacol Rev. 2016;68(2):476-532
166. Sandoo A, van Zanten JJCSV, Metsios GS, Carroll D, Kitas GD. The endothelium and its role in regulating vascular tone. Open Cardiovasc Med J.2010;4:302-312
167. Celermajer DS. Endothelial dysfunction: does it matter? Is it reversible? J Am Coll Cardiol. 1997;30(2):325-333
168. Lais LT, Shaffer RA, Brody J. Neurogenic and humoral factors controlling vascular resistance in the spontaneously hypertensive rat. Circulation Res. 1974;35(5):764-774
169. Grant MA, Karsan A. The blood vessel wall. Hematology 7th edn. 2018.https://www.sciencedirect.com/topics/medicine-and-dentistry/vascular-tone
170. Oishi P, Fineman JR, Regional circulation. In Pediatric Critical Care. 4th edn, 2011. https://www.sciencedirect.com/topics/medicine-and-dentistry/vascular-tone
171. Wickes D. Effects of thoracolumbar spinal manipulation on arterial flow in the extremity. J Manipulative Physiol Ther 1980;3(1):3-8
172. Carrick FR. Changes in brain function after manipulation of the cervical spine. J Manipulative Physiol Ther. 1997;20(8):529-545
173. Jeffery-Gauthier R, Guillemot J-P, Piché M. Neurovascular coupling during nociceptive processing in the primary somatosensory cortex of the rat. Pain 2013;154(8):1434-1341
174. Masamoto K, Kim T, Fukuda M, Wang P, Kim S-G. Relationship between neural, vascular, and BOLD signals in isoflurane-anesthetised rat somatosensory cortex. Cerebral Cortex 2007;17(4):942-950
175. Lee DD, Schwartz MA. Cell-cell communication breakdown and endothelial dysfunction. Crit Care Clin. 2020;36(2):189-200
176. Sato A, Schmidt RF. The modulation of visceral functions by somatic afferent activity. Japan J Physiol 1987;37:1-17
177. Uchida S, Bois S, Guillemot JP, Leblond H, Piché M. Systemic blood pressure alters cortical blood flow and neurovascular coupling during nociceptive processing in the primary somatosensory cortex of the rat. Neuroscince 2017;20:250-259
178. Wang H, Hitron IM, Iadecola C, Pickel VM. Synaptic and vascular associations of neurons containing cyclooxygenase-2 and nitric oxide synthase in a rat somatosensory cortex. Cereb Cortex 2005;15(8):1250-1260
179. Nakayama T, Suzuki A, Ito R. The articulo-cardiac sympathetic reflex in spinalised anesthetized rats. J Physiological Sci. 2006;56(2):137-43
180. Almohanna AM, Wray S. Hypoxic conditioning in blood vessels and smooth muscle tissues: effects on function, mechanisms, and unknowns. Am J Physiol Heart Circ Physiol. 2018;315(4):H756-H770
181. Karemaker JM. An introduction into autonomic nervous function. Physiol Meas. 2017;38(5):R89-R118
182. Shields RE. Functional anatomy of the autonomic nervous system, J Clin Neurophysiol. 1993;10(1):2-13
183. Daniel EE, Sarna S. The generation and conduction of activity in smooth muscle. Ann Rev Pharmacol Tocicol. 1978;18:145-166
184. Johansson B. Myogenic tone and reactivity: definitions based on muscle physiology. Hypertens Suppl. 1989;7(4):55-58
185. Webb RC, Smooth muscle contraction and relaxation. Adv Physiol Educ. 2003;27:201-206
186. Kurosawa M. [Effects of noxious and innocuous cutaneous stimulation on adrenal sympathetic efferent nerve activity in rats.] [Hokkaido Igaku Zasshi] Hokkaido J Med Sci 1985, 60(4):509-527
187. Fell C. Changes in blood flow distribution produced by central sciatic nerve stimulation. Am. J. Physiol. 214: 561–565, 1968
188. Jänig W. Central organization of somatosympathetic reflexes in vasoconstrictor neurons. Brain Res. 87: 305–312, 1975
189. Johansson B, Lundgren O, Mellander S. Reflex influence of 'somatic pressor and depressor afferents' on resistance and capacitance and on transcapillary fluid exchange. Acta Physiol Scand 1964;62(3):280-286
190. Johansson B. Circulatory responses to stimulation of somatic afferents. Acta Physiol. Scand. Suppl. 198: 1-91, 1962
191. Sato A. Neural mechanisms of somatic sensory regulation of catecholamine secretion from the adrenal gland. Adv Biopys. 1987;23:39-80

192. Karason AB, Drysdale IP. Somatovisceral response following osteopathic HVLAT: a pilot study on the effect of unilateral lumbosacral high-velocity-low-amplitude thrust technique on the cutaneous blood flow in the lower limb. J Manipulative Physiol Ther 2003;26(4):220-225
193. Lombardini R, Marchesi S, Collebrusco L, et al. The use of osteopathic treatment as adjuvant therapy in patients with peripheral arterial disease. Man Ther 2009;14:439-443
194. Schmorl G, Junghanns H. Inefficient Motor Segment (Intervertebral Insufficiency). In: The human spine in health and disease. 2nd ed. New York, Grune & Stratton. 1971; 213-229
195. Hadley LA. Intervertebral foramen and spinal nerve studies. In: Anatomico-roentgenographic studies of the spine. Springfield: Charles C Thomas. 1976:438
196. https://medical-dictionary.thefreedictionary.com/angiosome
197. Taylor GI, Corbett RJ, Ashton MW. The functional angiosomes implications of the anatomical concept. Plast Reconstr Surg 2017;140(4):721-733
198. Taylor GI, Palmer JH. The vascular territories (angiosomes) of the body: experimental studies and clinical applications. Br J Plast Surg. 1987;40:113-141
199. Fujii M, Terashi H. Angisome and tissue healing. Ann Vasc Dis 2019;12(2):147-50.
200. Kabra A, Suresh KR, Vivekanand V, et al. Outcomes of angiosome and non-angiosome targeted revascularisation in critical lower limb ischemia. J Vasc Surg. 2013;57:44-49
201. Alexandrescu VA, Söderström M, Venermo M. Andiosome theory: fact or fiction? Scand J Surg. 2012;101(2):125-31
202. Taylor GI. The angiosomes of the body and their supply to perforator flaps. Clin Plast Surg. 2003;30(3):331-42
203. Alexandrescu V, Söderström M, Venermo M. Angiosome theory: fact or fiction. Scand J Surg 2012;101:125-131
204. Inoue Y, Taylor GL. The angiosomes of the forearm: anatomic study and clinical implications.1996;98(2):195-210
205. Hong MK, Hong MK, Pan WR, Wallace D, Ashton MW, Taylor GI. The angiosomes territories of the spinal cord: exploring the issue of preoperative spinal angiography. Laboratory investigation. J Neurosurg Spine. 2008;8(4):352-364
206. Houseman ND, Taylor GI, Pan WR. The angiosomes of the head and neck: anatomic study and clinical applications. Plast Reconstr Surg. 2000;105(7):2287-313
207. Brodmann M. The angiosomes concept in clinical practice. Endovascular Today. 2013;May:60-61
208. Matthew MK, Hausman MR. Surgical approaches from angiosomal perspective. Clinicalgate. https://clinicalgate.com/surgical-approaches-from-an-angiosomal-perspective/ March 2015
209. Klabunde RE. Vascular tone. In: Cardiovascular physiology concepts. Philadelphia: Lippincott Williams & Wilkins. 2012. https://www.cvphysiology.com/Blood%20Flow/BF002
210. Korthuis RJ, Regulation of vascular tone in skeletal muscle, Basal hemodynamics. In: Skeletal muscle circulation. San Rafael. Morgan Clay Life Sciences.https://www.ncbi.nlm.nih.gov/books/NBK57142/. 2011
211. Noori S, Stavroudis TA, Seri I. Blood vessel tone. https://www.sciencedirect.com/topics/medicine-and-dentistry/blood-vessel-tone. In: Hemodynamics and cardiology: neonatology, questions and controversies. 2nd edn. 2012
212. Purves D, Augustine GJ, Fitzpatrick D, et al. The Visceral Motor System. editors. Neuroscience. 2nd edition. Sunderland (MA): Sinauer Associates; 2001. Chapter 21, https://www.ncbi.nlm.nih.gov/books/NBK11023/
213. Leach RA. Somatoautonomic reflex hypothesis. In: Leach RA, auth. The Chiropractic theories: a synopsis of scientific research, 2nd ed. Baltimore, MD: Williams & Wilkins, 1986:132-52
214. Johnston RJ. Vertebrogenic autonomic dysfunction - subjective symptoms: A prospective study. J Can Chiropractic Assoc 1981;25(2):51-57
215. Korr IM. Sustained sympathicotonia as a factor in disease. In: Korr IM, ed. The neurobiologic mechanisms of manipulative therapy. New York: Plenium Press; 1978;229-268
216. Lüscher TF, Tanner FC. Endothelial regulation of vascular tone and growth. Am J Hypertens 1993;6(7 Pt 2):263S-293S
217. Folkow B. Role of the nervous system in the control of vascular tone. Circulation 1960;21:760-769
218. Newman PP. Skeletal muscle tone and posture. In: Neurophysiology. Monographs in Modern Neurobiology. Dordrecht: Springer. 1980:227-37. https://doi.org/10.1007/978-94-011-6681-2_11
219. Vainer BG. FPA-based infrared thermography as applied to the study of cutaneous perspiration and stimulated vascular response in humans. Phys Med Biol. 2005;50(23):R63-94 (FPA = Focal Plane Array)
220. Tanaka T, Manabe N, Hata J, et al. Characterisation of autonomic dysfunction in patients with irritable bowel syndrome using fingertip blood flow. Neurogastroenterol Motil. 2008;20(5):498-504
221. Cramer G, Budgell B, Henderson C, Khalsa PS, Pickar JG. Basic science research related to chiropractic spinal adjusting the state of the art and recommendations revisited. J Manipulative Physiol Ther. 2006;29(9):726-61

222. Moraes JL, Rocha MX, Vasconcelos JE, et al. Advances in photoplethysmography signal analysis for biomedical applications. Sensors. 2018;18(6):1894. doi: 10.3390/s18061894
223. Kent C. Rhythms of the autonomic nervous system. J Vert Sublux Res. 1996;1(1):1-6. Citing: Korr IM. Andrew Taylor Still Memorial lecture: research and practice – a century later. J Am Osteopath Assoc. 1974;73:362-370 and, Uematsu S, Edwin DH, Jankel ER, et al. Quantification of thermal asymmetry. Part 1: Normal values and reproducibility. J Neurosurg. 1988;69:552-555.
224. Zubcevic J, Waki H, Raizada MK, Paton JFR. Autonomic-immune-vascular interaction, an emerging concept for neurogenic hypertension. Hypertension. 2011;57:1026-1033
225. Tomson TT, Arora R. Modulation of cardiac potassium current by neural tone and ischemia. Card Electrophysiol 2016;8(2):349-360
226. Marina N, Abdala APL, Korsak A, et al. Control of sympathetic vasomotor tone by catecholaminergic C1 neurones of the rostral ventrolateral medulla oblongata. Cardiovasc res. 2011;91(4):703-10
227. Senzon S. Sequential development of the neuropathy In: Segmental neuropathy, the fist evidence of developing pathology. 2nd edn. The Institute Chiropractic Senzon Learning. https://www.institutechiro.com/waves/1928-1975/sixth-wave-chiropractic/segmental-neuropathy/sequential-development-neuropathy/. 2014
228. Szaraz ZT. The thoracic outlet syndrome: first rib subluxation syndrome. Musculoskeletal Key. 455-474 https://musculoskeletalkey.com/the-thoracic-outlet-syndrome-first-rib-subluxation-syndrome/
229. Libre Texts. Structure and function of blood vessels. In: The Cardiovascular System: Blood Vessels and Circulation. https://opentextbc.ca/anatomyandphysiology/chapter/20-1-structure-and-function-of-blood-vessels/. Downloaded Nov 2, 2018
230. Anatomy & Physiology. Provided by: OpenStax CNX. Located at: http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22@8.25. Structure and function of blood vessels. https://courses.lumenlearning.com/suny-ap2/chapter/structure-and-function-of-blood-vessels/. Downloaded Nov 2, 2018
231. Sato A, Swenson RS. Sympathetic nervous system response to mechanical stress of the spinal column in rats. J Manipulative Physiol Ther. 1984;7:141-7
232. Budgell B. The reflex effect of subluxation: the autonomic nervous system. Dynamic Chiropr. 1999;17(22): https://www.dynamicchiropractic.com/mpacms/dc/article.php?id=36314
233. Freund PR, Rowell LB, Murphy TM, Hobbs SF, Butler S H. Blockade of the pressor response to muscle ischemia by sensory nerve block in man. Am. J. Physiol; 1979;237: H433–H439
234. Stornetta RL, Morrison SF, Ruggiero DA, Reis DJ. Neurons of rostral ventrolateral medulla mediate somatic pressor reflex. Am J Physiol 1989;252(2 Pt 2):R448-462
235. Knutson GA. Significant changes in systolic blood pressor post vectored upper cervical adjustment vs resting control groups: a possible effect of the cervicosympathetic and/or pressor reflex [clinical trial]. J Manipulative Physiol Ther 2001;24(2):101-109
236. Mitchell JH, Schmidt RF. Cardiovascular reflex control by afferent fibers from skeletal muscle receptors. Compr Physiol 2011, Supplement 8: Handbook of Physiology, The Cardiovascular System, Peripheral Circulation and Organ Blood Flow. 1983:623-658. doi: 10.1002/cphy.cp020317
237. Kirillova-Woytke I, Baron R, Jänig W. Reflex inhibition of cutaneous and muscle vasoconstrictor neurons during stimulation of cutaneous and muscle nociceptors. J Neurophys 2014;111(9):1833-1844
238. Cicchitti L, Martelli M, Cerritelli F. Chronic inflammatory disease and osteopathy: a systematic review. PLOS One. 2015 Mar 17;10(3):e0121327. doi: 10.1371/journal.pone.0121327
239. Yun AJ. Adventitial dysfunction: and evolutionary model understanding atherosclerosis. Med Hypotheses 2005;65(5):962-965
240. Cau SBA, Evora PRB, Tostes RC. Vasoconstrictor substances produced by the endothelium. In: Da Luz PL, Libby P, Laurindo FRM. Eds. Endothelium and cardiovascular diseases 2018:115-125. https://doi.org/10.1016/B978-0-12-812348-5.00009-X
241. Antonaci F, Rossi E, Voiticovschi-Iosob C, Dalla Volta G, Marceglia S. Frontal infrared thermography in health individuals and chronic migraine patients: reliability of the method. Cephalalgia. 2019;39(4):489-496
242. van der Velde AR, Meijers WC, de Boer RA. Endothelial dysfunction. In: Wehling M Ed. Principles of translational science in medicine, 2nd edn. 2015:167-183
243. Gashev AA. Physiologic aspects of lymphatic contractile function: current perspectives. Ann N Y Acad Sci 2002;979,178-196.
244. Wang Y, Jin Y, Mäe MA, et al. Smooth muscle cell recruitment to lymphatic vessels requires PDGFB and impact vessel size but not identity. Development 2017;144(19):3590-3601
245. Grossbard BP, Loughin CA, Marino DJ, et al. Medical infrared imaging (thermography) of type I thoracolumbar disc disease in chondrodystrophic dogs. Vet Surg 2014;43(7):869-876
246. Harrap MJM, de Ibarra NH, Whitney HM, Rands SA. Reporting of thermography parameters in biology: a systematic review of thermal imaging literature. Royal Society of Science. 2018. https://doi.org/10.1098/rsos.181281
247. Harris W, Wagnon RJ. The effects of chiropractic adjustments on distal skin temperature. J Manipulative Physiol Ther 1987;10(2):57-60

248. MacRae BA, Annaheim S, Spengler CM, Rossi RM. Skin temperature measurement using contact thermography: a systematic review of setup variables and their effect on measured values. Front Physiol 2018;9:1-24
249. MacRae BA, Annaheim S, Spengler CM, Rossi RM. Validity of contact skin temperature sensors under different environmental conditions with and without coverage: characterisation and correction. Int J Biometeorology 2018;62:1861-1872
250. McCoy M, Campbell I, Stone P, Fedorchuk C, Wijayawardana S, Easley K. Intra-examiner and inter-examiner reproducibility of paraspinal thermography. PLoS One 2011;6(2):e 16535. doi. 10.1371/journal.pone.0016535
251. Polidori G, Kinne M, Mereu T, Beaumont F, Kinne M. Medical infrared thermography in back pain osteopathic management. Complement Ther Med 2018;39:19-23
252. Foreman RD, Qin C, Jou CJ. Spinothalamic system and viscerosomatic motor reflexes: functional organisation of cardiac and somatic input. In: King HH, Jänig W, Patterson MM. The science and clinical application of manual therapy. Edinburgh: Churchill Livingston. 2011;111-127
253. Einaudi G. [Research on vasomotor disorders of upper extremities present in patients with cervicalgia and cervicobrachialgia; changes induced by static variations of the cervical spine.] Reumatismo 1959;11(3):173-178 (Italian)