Hypothesis

From Vasomotion to Interoception: The PULSE-V Hypothesis of Predictive Tissue Regulation in Manual Medicine

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Abstract

Manual medicine has long outgrown explanations that rest solely on structural-biomechanical correction. While the techniques reliably alleviate musculoskeletal pain and functional complaints, the evidence suggests that durable benefit depends far less on lasting mechanical realignment than on a distributed set of neurophysiological, autonomic, interoceptive and contextual processes. A persistent translational gap nevertheless remains between these abstract predictive models of bodily regulation and the tangible, regional tissue dynamics that clinicians encounter in practice. We propose PULSE-V (Predictive Updating of Local Somatic Errors via Vasomotion) as a hypothesis-generating framework that seeks to narrow that gap. The central suggestion is that coherent low-frequency vasomotor oscillations (~0.1 Hz) within angiosomes may serve as a candidate biophysical substrate capable of organising ascending interoceptive signals. When coherence is disrupted, the resulting noisy afferent stream may contribute to interoceptive prediction error. Chronic somatic dysfunction can then be understood as a form of allostatic interoceptive overload — a self-stabilising loop in which ambiguous peripheral input, impaired sensory attenuation and entrenched top-down priors reinforce one another. PULSE-V is offered as a deliberately falsifiable programme rather than a settled theory. It generates testable predictions concerning regional vasomotor patterns, multimodal biomarker signatures and the differential contributions of vasomotor, affective-touch and relational elements in treatment. Should the evidence support it, the model may help account for the frequently observed discrepancy between the modest mechanical effects of manual intervention and the substantial clinical outcomes that follow.

Keywords: active inference; interoception; vasomotion; angiosomes; manual therapy; osteopathy

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1. Introduction: From Biomechanical Correction to Predictive Regulation

Manual therapy and osteopathic manipulative treatment continue to occupy a central place in the management of musculoskeletal pain and functional disorders [1,2]. For much of the twentieth century the prevailing explanatory framework was straightforward: practitioners identify a mechanical fault — restricted joint mobility, positional asymmetry, altered tissue texture — and apply a corrective force to restore normal alignment or movement [3]. This structural-biomechanical account was intuitively appealing and closely aligned with clinical experience.

Over recent decades, however, that narrative has become increasingly difficult to defend. Inter-rater reliability for the palpatory detection of discrete structural abnormalities remains modest [3]. Objective evidence of sustained positional change following intervention is sparse [4]. Clinical outcomes show surprisingly weak correlation with the mechanical variables that were ostensibly addressed [5]. Concurrently, a growing body of clinical and experimental studies indicates that manual interventions engage a wide array of distributed mechanisms: descending nociceptive modulation [6], autonomic tone shifts [7], affective touch pathways [8], expectation effects [9] and the

quality of the therapeutic relationship [10]. The conventional distinction between "specific" biomechanical actions and "non-specific" contextual influences has therefore lost much of its explanatory utility [11].

In parallel, neuroscience has moved decisively towards predictive accounts of perception and bodily regulation [12,13]. Allostasis and active inference describe the brain as an anticipatory system that generates internal models of bodily state and updates them by minimising prediction error. Interoception, within this paradigm, is not the passive reception of visceral signals but an active inferential process in which descending expectations are continually tested against ascending evidence [2,12]. Applied to persistent pain and somatic dysfunction, this perspective suggests that bodily distress arises not only from local tissue events but also from maladaptive inferential dynamics — situations in which poorly structured or noisy peripheral input fails to dislodge entrenched, threat-oriented priors [5,14].

This conceptual shift creates a clear translational challenge. Predictive frameworks are elegant at the computational level yet remain abstract when one attempts to relate them to the regional tissue phenomena that clinicians palpate daily [1,3]. Manual practitioners work with changes in tissue texture, vascularity, resistance, tenderness and dynamic compliance. Predictive neuroscience speaks of precision weighting, generative models and free-energy minimisation [12,13]. The two domains seldom connect in a concrete way.

The vascular system offers a particularly promising point of contact [15]. Manual techniques consistently produce measurable alterations in peripheral perfusion and autonomic balance [4,7,16], yet no widely accepted model explains how these local vascular-tissue events could influence central interoceptive inference [2,17,18]. The hypothesis set out below is an attempt to address precisely that question.

2. The Core Hypothesis of PULSE-V

PULSE-V rests on a single testable premise: regional vascular-tissue dynamics may constitute the missing physiological link between manual medicine and predictive neuroscience [1,11]. More specifically, the model suggests that angiosomes may serve as plausible peripheral units of functional regulation [15,19], that the microcirculatory-tissue system may operate as a distributed sensorimotor interface [20], and that coherent vasomotor oscillations may provide a candidate biophysical substrate for organising ascending interoceptive signals [17].

The angiosome concept stands at the heart of this proposal [19]. Originally developed in reconstructive surgery, an angiosome describes a three-dimensional tissue territory supplied by a single source artery and characterised by its local vascular architecture [15]. In the present framework we reconceptualise the angiosome as a regional physiological domain in which multiple tissue layers share a common haemodynamic resource and, potentially, a coordinated oscillatory state [15,19,21]. Because these tissues are coupled through microvascular supply, metabolic demand and vasomotor interaction, the angiosome presents itself as an anatomically coherent unit for local predictive regulation [20,22].

Within this domain the microcirculatory-tissue system functions as considerably more than a passive conduit for blood [20,23]. Vessel walls, perivascular tissues, stromal elements, connective matrices and metabolically sensitive afferents together constitute a distributed transduction interface [8,23]. The state of the tissue is therefore not represented by a static parameter such as pressure or flow rate, but by a dynamically organised vascular-tissue pattern [21,22].

The principal candidate signal within this pattern is vasomotion — the spontaneous low-frequency oscillation of microvascular tone [15,20,24]. We do not contend that vasomotion exclusively encodes interoceptive information. Rather, we propose that coherent vasomotor oscillations may help structure ascending afferent input, conferring temporal organisation, salience and functional precision on signals generated within vascularised tissue [17,25]. When coherence is disrupted — whether through reduced multiscale complexity or maladaptive flow redistribution — the afferent stream becomes ambiguous and noisy [5,26].

Vasomotor coherence is therefore advanced as a candidate biophysical basis for informative regional bodily signalling [17]. Vasomotor decoherence, conversely, is advanced as a possible peripheral physiological correlate of interoceptive prediction error — one condition under which ambiguous peripheral evidence fails to prompt meaningful updating of central models [5,27].

3. Mechanistic Rationale: A Hierarchical Bridge from Tissue to Inference

The mechanistic rationale of PULSE-V can be traced as a reciprocal cascade linking regional vascular dynamics to central interoceptive regulation [2,27]. Rather than supposing that the brain receives a direct pictorial representation of tissue state, we suggest that peripheral vascular organisation fundamentally shapes the way bodily information is filtered, weighted and integrated across multiple physiological levels [11,12].

The sequence begins locally. Within a given angiosomal territory, chronic mechanical stress, persistent postural loading, microischaemia or unresolved inflammation disrupts the natural variability of microvascular oscillations [15,20]. This does not necessarily entail overt vascular failure; it entails a shift towards more rigid, less coordinated and therefore less informative microcirculatory dynamics [26]. That altered local environment immediately affects sensory transduction. Polymodal and thin-fibre afferents — highly responsive to mechanical tension, temperature, chemical milieu and ischaemic metabolites — transduce the disrupted rhythm, generating a fragmented and noisy ascending stream [8,28]. Tissue perturbation matters here not merely because it compromises perfusion, but because it compromises the informational quality of the evidence reaching higher regulatory centres [17,21].

These signals ascend via lamina I pathways, brainstem autonomic nuclei and thalamic relays to reach posterior insular representations [2,27]. We propose that spatially organised aspects of this thin-fibre input may contribute to cortical interoceptive mapping. At this level ascending evidence meets descending allostatic predictions [6,12]. In a well-regulated system precise peripheral signals continually refine cortical models. When the afferent stream is chronically noisy or assigned low precision — owing to peripheral vasomotor decoherence — it may fail to dislodge maladaptive priors [5,14]. The system then defaults to established expectations of threat, pain or functional deficit, actively attenuating or discounting ambiguous peripheral data [29,30].

This inferential mismatch tends to become self-sustaining. In order to minimise prediction error, the nervous system generates compensatory efferent outputs — regional vasoconstrictive bias, protective muscle activation, altered tissue loading [4,7]. These responses further compromise local perfusion, perpetuating vascular decoherence and progressively stabilising a maladaptive attractor state [5,27]. Chronic somatic dysfunction thus arises not solely from peripheral tissue events, nor exclusively from aberrant cortical prediction, but from a progressive failure of reciprocal regulation across scales [31].

By situating manual medicine within this network-physiology perspective, PULSE-V casts clinical touch as a targeted perturbation capable of disrupting a dysregulated multi-level system [3,21].

4. Clinical Implications of the Hypothesis

Should PULSE-V prove broadly correct, manual intervention would modulate chronic dysfunction through the interplay of at least three partially overlapping channels [1,11].

The first is vasomotor. Mechanical loading, fascial decompression, rhythmic stretching and shear stress can alter local haemodynamics and may help restore coherence in regional vascular oscillations [15,20]. In predictive terms this reduces ambiguity in the peripheral signal, thereby increasing the probability that ascending input can contribute to updating higher-order cortical predictions [12,17]. This channel may be particularly relevant when tissues present as congested or dynamically restricted — presentations in which vascular-tissue dysregulation may play a substantial role alongside any purely mechanical component [4,7].

The second is C-tactile. Slow, affective touch engages thin-fibre afferents that project directly to posterior insular networks and are closely associated with safety and autonomic downregulation [2,8]. This stream of input can compete with threat-related signals and may assist in recalibrating the salience of bodily information [5,11]. Clinical experience suggests that the effectiveness of an intervention often depends less on the intensity of mechanical force than on the quality of contact — a quality that is frequently affective and relational [10].

The third is interpersonal and contextual. The therapeutic alliance, patient expectation and the perceived meaning of the encounter act as powerful top-down modulators of precision weighting [9,10]. Contextual factors do not merely accompany the technique; they actively alter which sensory signals are amplified and which are attenuated [11,32]. This helps to account for the substantial variability in outcome when apparently similar manual methods are applied by different practitioners or in different relational settings [3].

These channels are not mutually exclusive; they operate concurrently and in synergy [21,22]. Their relative dominance will vary according to the individual patient, the tissue involved and the chronicity of the complaint. PULSE-V therefore offers a flexible conceptual structure for understanding why manual interventions that appear technically comparable can produce markedly different clinical results [1,3].

5. Testable Predictions and Methodological Approach

The principal merit of PULSE-V lies in its falsifiability. The model generates several predictions that can, in principle, be refuted.

At the peripheral level, microcirculatory oscillations should exhibit significantly greater coherence within functionally linked angiosomal territories than across adjacent but haemodynamically distinct regions [15]. Moreover, clinically effective manual interventions should be associated with measurable improvements in regional vasomotor coherence or multiscale complexity in at least a substantial proportion of cases [24,26].

These peripheral changes should not remain isolated. If the hypothesis holds, they should correlate reliably with alterations in central interoceptive markers, autonomic indices or pain-related outcomes — rather than aligning solely with subjective reports [33–36]. Distinct therapeutic signatures may also emerge depending on whether the intervention primarily engages vasomotor, affective-touch or contextual channels [17].

Empirical evaluation requires a multimodal approach [21,22]. Established tools include laser Doppler flowmetry, photoplethysmography [25], near-infrared spectroscopy and heart rate variability analysis [7]. Where feasible, these can be combined with neuroimaging sensitive to insular and salience-network dynamics [2]. Because the model spans multiple physiological scales, a convincing result would demonstrate coordinated shifts across peripheral, autonomic and central domains [4,21]. Conversely, the hypothesis would be substantially weakened if regional vascular dynamics showed no reproducible relationship with interoceptive proxies, or if marked clinical improvement routinely occurred in the absence of any detectable change in vascular-tissue organisation [37].

6. Limitations

We must acknowledge the boundaries of the present framework [38]. PULSE-V is an interpretive hypothesis rather than a fully validated physiological theory. Several of its proposed links remain inferential [37]. Direct empirical evidence for angiosome-specific interoceptive coding is still developing [19], and the precise role of choke-vessel dynamics in active inference awaits systematic experimental investigation. There is also a standing risk of overextending computational concepts onto biological tissue without adequate empirical support [13].

The model has also been deliberately circumscribed in scope in order to maintain a clear focus on vascular dynamics. As a consequence it does not yet fully incorporate the substantial contributions

of humoral, glial, endocrine, immune and microbiome factors to chronic dysfunction [21,39–41], nor does it provide a formal computational implementation with quantified parameters [14]. The clinical implications discussed here are therefore hypothesis-guided rather than prescriptive; their primary purpose is to stimulate experimentally tractable questions rather than to dictate clinical practice [38].

7. Conclusions

PULSE-V offers a translational hypothesis that connects angiosomal tissue organisation, microcirculatory dynamics and active interoceptive inference within a single framework. It suggests that coherent vasomotor behaviour may help organise ascending bodily signals, while vascular-tissue decoherence may contribute to maladaptive inference in chronic somatic dysfunction. By reframing manual intervention as a multilevel perturbation of predictive tissue regulation rather than as simple mechanical correction, the model may provide a testable basis for further investigation in manual medicine, interoception research and regional neurovascular physiology.

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