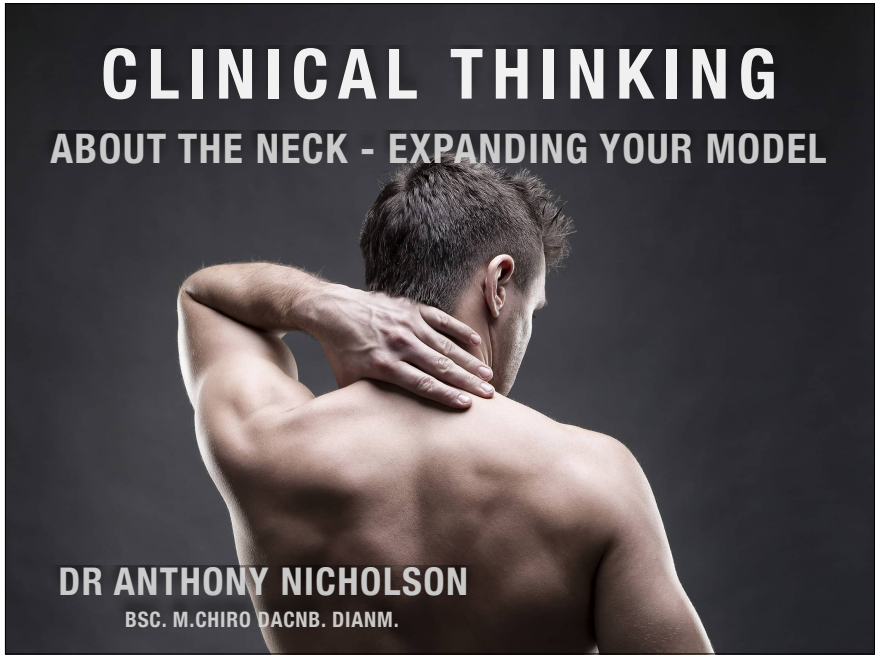


Bob is 65-years-old and has suffered recurrent neck pain for many years. He complains of significant neck stiffness and has difficulty turning his head to the left side, and has noticed an unusual aching sensation in his left parascapular area over recent weeks. Bob tends to succumb to a 'wry neck' every couple of years. Furthermore, he's started to suffer dizzy sensations when looking down to hit a golf ball. He often feels disorientation for a short time afterwards.

What is the likely diagnosis?

What has gone ‘wrong’?

What do you aim to achieve with your treatment?

MODELS DETERMINE HOW WE THINK, REASON AND ACT

WHY ARE MODELS IMPORTANT?

Models give us structure and meaning

They provide a mental process for making sense of an over-whelming amount of information

They frame the reality that we impose on the world

Models guide decision-making

MODELS CAN BE LIMITING

NOT JUST A PILE OF FACTS

Models help us to see relationships and understand the order of actions to solve problems and achieve specific goals

To improve our own models, we need to understand how they're formed in the neocortex

A MODEL FOR THE CERVICAL SPINE

Pain as a protective behaviour

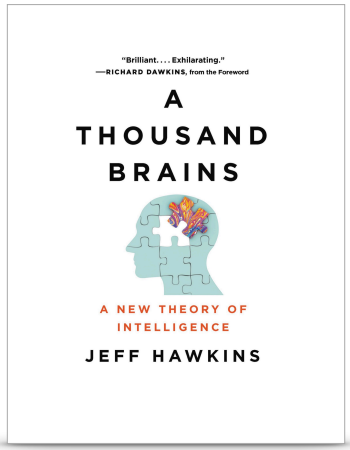
Cortical representation (model)

Balance, posture and sensorimotor control

Biomechanics and pathoanatomy

Red flags

THE NEOCORTEX IS THE ORGAN OF HUMAN INTELLIGENCE



THE NEOCORTEX IS THE ORGAN OF HUMAN INTELLIGENCE

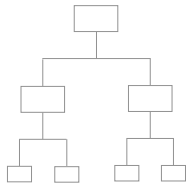
The brain evolved by adding new parts on top of older parts. The newest part of the brain is the neocortex, which means 'new outer layer' and is only present in mammals

The human neocortex is especially large (70% of the brain by volume) and gives rise to almost all of the capabilities that we think of as intelligence - vision, language, music, mathematics, science, clinical reasoning and

THE NEOCORTEX IS THE ORGAN OF HUMAN INTELLIGENCE

THE NEOCORTEX IS THE ORGAN OF HUMAN INTELLIGENCE

The prevailing view has been the neocortex works in a hierarchical way - like a flowchart of feature detectors. But evidence now supports a new perspective



Each mm^2 of neocortex (2.5 mm^3) has about 100,000 neurons, 500 million synapses and several km of axons and dendrites

Each regions must be performing something far more complex than feature detection

SAME BASIC MECHANISM?

THE FUNDAMENTAL UNIT OF THE NEOCORTEX IS THE CORTICAL COLUMN

While the evolutionary development of the brain involved adding new parts on top of old parts, this is not how the neocortex grew to make up 70% of our brain volume. It got larger by making more copies of the same basic unit - the cortical column

The human neocortex consists of approximately 150,000 cortical columns stacked side-by-side, each 2.5mm long and occupying 1 mm square

All of the cells in a column respond to a receptive field - small part of retina or patch of skin for example

A NEW THEORY OF NEOCORTICAL FUNCTION

Every part of the neocortex works on the same principle - all intelligence, from vision to touch to language and higher cognitive functions, are manifestations of the same underlying cortical algorithm

There are no pure motor or sensory regions. What differentiates a region is not its intrinsic function, but what it's connected to

Each area of neocortex learns a model of whatever input it receives

THE NEOCORTEX LEARNS A MODEL OF THE WORLD

Not simply an input-output system. Neocortex learns from inputs and then later may act differently

Every column is a sensorimotor modelling system. The neocortex makes predictions based upon its models

THE NEOCORTEX CONSTANTLY PREDICTS ITS INPUTS

Every cortical column makes predictions - an inherent property of the neocortex. Predictions happen constantly in every sensory modality

HIGHER KNOWLEDGE IS STORED IN CONCEPTUAL MODELS

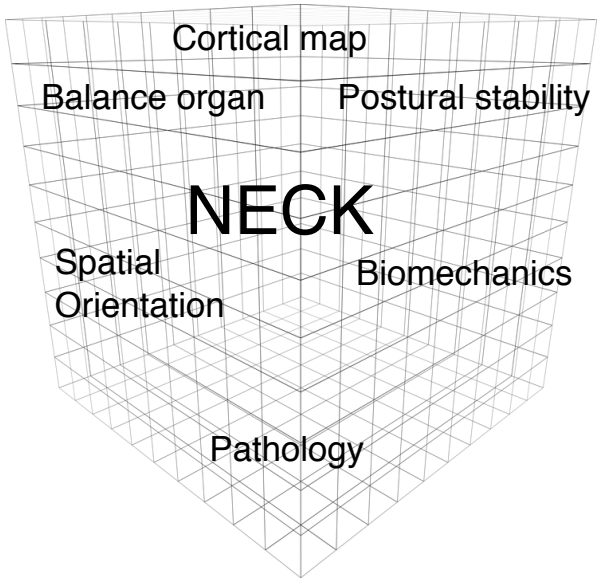
Conceptual knowledge

Language

High level thought

Concepts such as democracy, mathematics or clinical diagnosis are not just a pile of facts

We are able to reason about them and make predictions about what might happen



THE NECK AS A MECHANICAL SYSTEM

Where is the neck vulnerable?

What hurts and what fails?

HOW WELL CAN YOU VISUALISE THE NECK?

How good is your visual model. How could you expand it?

WHY C5/C6?

Highest incidence of:

- Arthrosis
- Disc degeneration
- Disc protrusion
- Modic changes

Most mobile
Least stable with CDD
Most narrow IVFs
Large cord cross section
V2 segment of vertebral artery

WE MUST CONSIDER...

How do we get therapeutic leverage upon the neck's sensory machinery but at the same time be very conservative with applying forces to its mechanical machinery?

THE NECK AS A MECHANICAL SYSTEM

- Cervical disc degeneration (CDD) and instability
- Uncinate joints - guide rails for sagittal movement
- Degenerative instability
- Cervical arteries
- Facet joints and synovial folds
- Radicular pain and radiculopathy (nerve root insult and compression)
- Cervical canal stenosis and myelopathy

CERVICAL DISC DEGENERATION

Often begins in adolescence and is almost universal after age 45 years

JOURNAL OF MANUAL & MANIPULATIVE THERAPY
https://doi.org/10.1080/10669817.2021.2000089

Cervical disc degeneration: important considerations for the manual therapist

Brian T. Swanson[a] and Douglas Creighton[b]

[a]Department of Rehabilitation Sciences University of Hartford, West Hartford, CT, USA; [b]Human Movement Science Department Oakland University, Rochester, MI, USA

ABSTRACT

Cervical disc degeneration (CDD) is a progressive, age-related occurrence that is frequently associated with neck pain and radiculopathy. Consistent with the majority of published clinical practice guidelines (CPG) for neck pain, the 2017 American Physical Therapy Association Neck Pain CPG recommends cervical manipulation as an intervention to address acute, subacute, and chronic symptoms in the 'Neck Pain With Mobility Deficits' category as well for individuals with 'Chronic Neck Pain With Radiating Pain'. While CPGs are evidence-informed statements intended to help optimize care while considering the relative risks and benefits, these guidelines generally do not discuss the mechanical consequences of underlying cervical pathology nor do they recommend specific manipulation techniques, with selection left to the practitioner's discretion. From a biomechanical perspective, disc degeneration represents the loss of structural integrity/failure of the intervertebral disc. The sequelae of CDD include posterior neck pain, segmental hypermobility/instability, radicular symptoms, myelopathic disturbance, and potential vascular compromise. In this narrative review, we consider the mechanical, neurological, and vascular consequences of CDD, including information on the anatomy of the cervical disc and the mechanics of discogenic instability, the anatomic and mechanical basis of radiculitis, radiculopathy, changes to the intervertebral foramen, the importance of Modic changes, and the effect of spondylotic hypertrophy on the central spinal canal, spinal cord, and vertebral artery. The pathoanatomical and biomechanical consequences of CDD are discussed, along with suggestions which may enhance patient safety.

KEYWORDS

Cervical spine; manual therapy; biomechanics; clinical decision making; degenerative disc; spondylosis

NOT MINIATURE LUMBAR DISCS

Less well-defined nuclear/annular structure - less proteoglycan

No discrete annulus at the posterior disc margin

Nucleus is approximately 30% of disc material (vs 50% in lumbar spine)

Average thickness is 4-5mm (thickest at C5)

CLEFTS AND FISSURES FORM

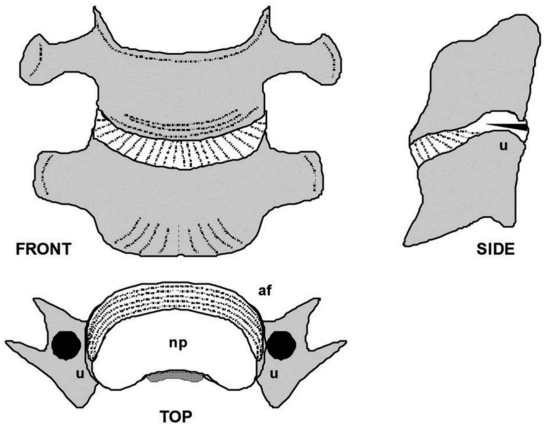


Diagram reproduced from: Swanson, B. T. & Creighton, D. Cervical disc degeneration: important considerations for the manual therapist. J Man Manip Ther 1–15 (2021) doi:10.1080/10669817.2021.2000089.

AXIS OF ROTATION SHIFTS ANTERIORLY

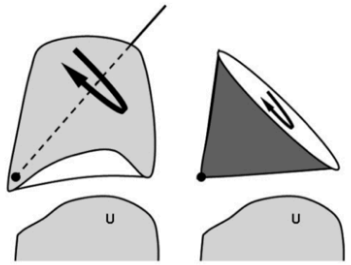
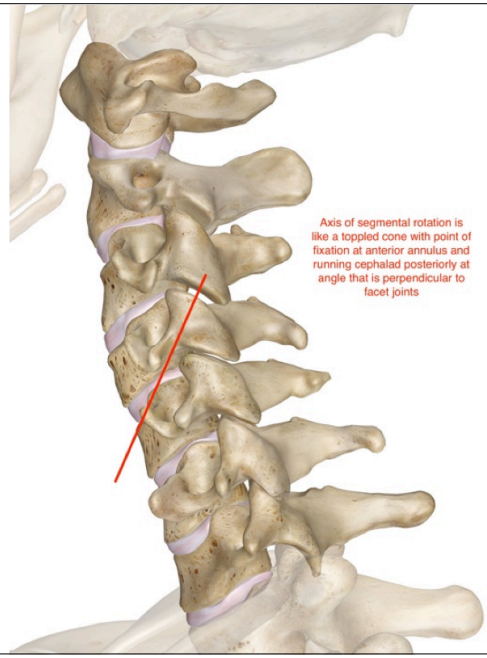


Figure 2. Sketches of the movements of a cervical interbody joint in side view. The anterior end of the upper vertebral body is held in place by the anterior anulus fibrosus. The posterior end of the upper vertebral body has a transversely convex lower surface that rotates above and between the uncinate processes (u), around an axis that passes cephalad, and posteriorly, perpendicular to the planes of the zygapophysial joints. This movement can be likened to that of a toppled cone, whose apex is fixed, but whose base is free to spin around the long axis of the cone.

Diagram reproduced from: Swanson, B. T. & Creighton, D. Cervical disc degeneration: important considerations for the manual therapist. J Man Manip Ther 1–15 (2021) doi:10.1080/10669817.2021.2000089.



WHAT ABOUT DISC PAIN?

Free nerve endings in the outer third of the annulus posteriorly (branches of the sinuvertebral nerve), laterally (vertebral nerve), and anteriorly (branches of the cervical sympathetic trunks)

NEOINNERVATION

The development of neck pain in individuals with CDD and positive findings on discography has been associated with neoinnervation, with extensive ingrowth of substance-P sensitive fibres observed extending into the nuclear region.

Wu B, Yang L, Peng B. Ingrowth of nociceptive receptors into diseased cervical intervertebral disc is associated with discogenic neck pain. Pain Med. 2019;20 (6):1072–1077.

Journal of Pain Research

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PERSPECTIVES

Cervical disc degeneration and neck pain

This article was published in the following Dove Press journal:
Journal of Pain Research

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Michael J DePalma[2]

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Abstract: Cervical intervertebral disc has long been considered a common source of neck pain. However, the pain caused by the disc itself has not been clearly defined so far, and its diagnosis and treatment has always been controversial. Degenerative cervical disc has a rich supply of nerve fibers, is prone to inflammatory reactions, and is susceptible to pain that can be provoked by disc stimulation or distention, and can be eliminated by block. Overwhelming clinical evidence demonstrates that neck pain in patients with degenerative cervical radiculopathy or myelopathy can be subsided rapidly by anterior cervical surgery, further indicating that this neck pain stems from the pathology of cervical disc itself. Cervical discography is advocated as the only test that connects disease to symptoms, but the procedure remains controversial. If strict criteria and technique are maintained, discography can discriminate painful, symptomatic discs from nonpainful, asymptomatic discs. Discogenic neck pain alone without cervical disc herniation or cervical spondylosis accounts for a large proportion of chronic neck pain. For these patients who continue to have refractory neck pain and fail to respond to conservative treatment, anterior cervical fusion surgery or artificial cervical disc replacement may be a better choice, and preoperative cervical discography can guarantee the excellent surgical results. Existing basic and clinical studies have scientifically shown that cervical intervertebral disc degeneration can lead to neck pain.

Keywords: cervical intervertebral disc, chronic neck pain, discogenic neck pain, disc degeneration, anterior cervical surgery, cervical discography

"Changes of structure and function of cervical disc with degeneration is related to neck pain. This neck pain is usually accompanied by stiffness of the neck, headache, unilateral or bilateral shoulder pain, non-root arm pain, ocular and vestibular dysfunction, and pain in the anterior chest wall."

"Discogenic neck pain alone without cervical disc herniation or cervical spondylosis accounts for a large proportion of chronic neck pain, and the reported prevalence is between 16% and 41%."

HERNIATIONS CAN BE ASYMPTOMATIC

ELSEVIER

European Journal of Radiology 55 (2005) 409–414

EJR
EUROPEAN JOURNAL OF RADIOLOGY

www.elsevier.com/locate/ejrad

Prevalence of annular tears and disc herniations on MR images of the cervical spine in symptom free volunteers

C.W. Ernst*, T.W. Stadnik, E. Peeters, C. Breucq, M.J.C. Osteaux

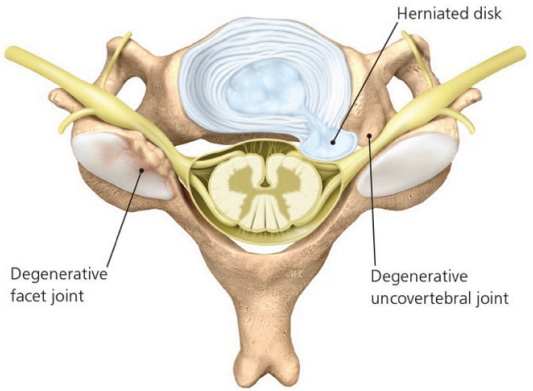
Department of Radiology and Medical Imaging, University Hospital V.U.B., Laarbeeklaan 101, 1090 Brussels, Belgium

Received 3 May 2004; received in revised form 29 October 2004; accepted 10 November 2004

"An asymptomatic population demonstrates a high (37% in our study) prevalence of annular tears on MR-images…

Our results confirm previously reported prevalence of bulging discs (73%) and protrusions (50%) in a asymptomatic population. In our population, we found only one (3%) extruded disc. These findings may support the hypothesis that extruded discs are well correlated with neck pain or brachialgia but need further investigation."

RADICUAR SYMPTOMS



Herniation is almost always median or paramedian due to uncinate buttress posterolaterally

"Similar to the lumbar region, extrusions, migrated disk material, and laterally situated disk herniations are more likely to undergo spontaneous regression. As most lesions causing cervical radicular pain are not purely soft disk, but at least in part bony, overall regression of the root compressive lesion is less likely than in the lumbar region."

Spine

SPINE Volume 42, Number 5, pp 311–317

CERVICAL SPINE

Management of Symptomatic Cervical Disk Herniation

A Survey Among Dutch Neurosurgeons

Judith D. de Rooij, MSc, PT,[*,†,‡] Pravesh S. Gadjradj, BSc,[*] Frank J. Huygen, MD, PhD,[†] Pim A.J. Luijsterburg, PhD,[§] and Biswadjiet S. Harhangi, MD, PhD[*]

"A minimum duration of 8 to 12 weeks of radicular arm pain was considered the optimal timing to perform surgery for cervical disc herniation by the majority of the neurosurgeons."

UNCINATE JOINTS - WHY?

Found cranially at the level of the 3rd cervical vertebra and extend caudally to as low as the 2nd thoracic vertebra – but most commonly C3-C7

Contribute to mobility and stability as well as to protect the IVF contents from herniated disc

Guide rails to control anteroposterior translation in sagittal plane

IVF ENCROACHMENT

Diagram reproduced from: Swanson, B. T. & Creighton, D. Cervical disc degeneration: important considerations for the manual therapist. J Man Manip Ther 1–15 (2021) doi:10.1080/10669817.2021.2000089.

BE MINDFUL OF CERVICAL IVF

Typical IVF measures approximately 10 mm vertical diameter, 5 mm AP diameter, 4 mm in length – like a tall rectangular window with height twice its width

Nerve roots generally occupy approximately 25–50% of the foraminal area in healthy spines

When compared with normal IVF diameters, disc space narrowing affects foramina area:

1 mm = 20% to 30% reduction
2 mm = 30% to 40% reduction
3 mm = 35% to 45% reduction

NERVE ROOT INSULT

Mechanical insult:

Radiculitis can result from excessive segmental translatory motion or angular motion. Be mindful of instability and positioning.

Vascular insult:

Narrowing may compress the radicular arteries within the dural root sleeves, leading to decreased vascular perfusion. Venous obstruction can lead to oedema.

FACET JOINTS, MENISCOIDS AND SYNOVIAL FOLDS

FACET JOINTS, MENISCOIDS AND SYNOVIAL FOLDS

Although the diagnosis of Z joint pain is well accepted in a post-trauma scenario, there is still significant debate about the actual tissue source of pain

The joint capsules are often cited as the major culprit, although meniscoid synovial folds have also been shown to suffer damage during whiplash, resulting in haemorrhage and pain

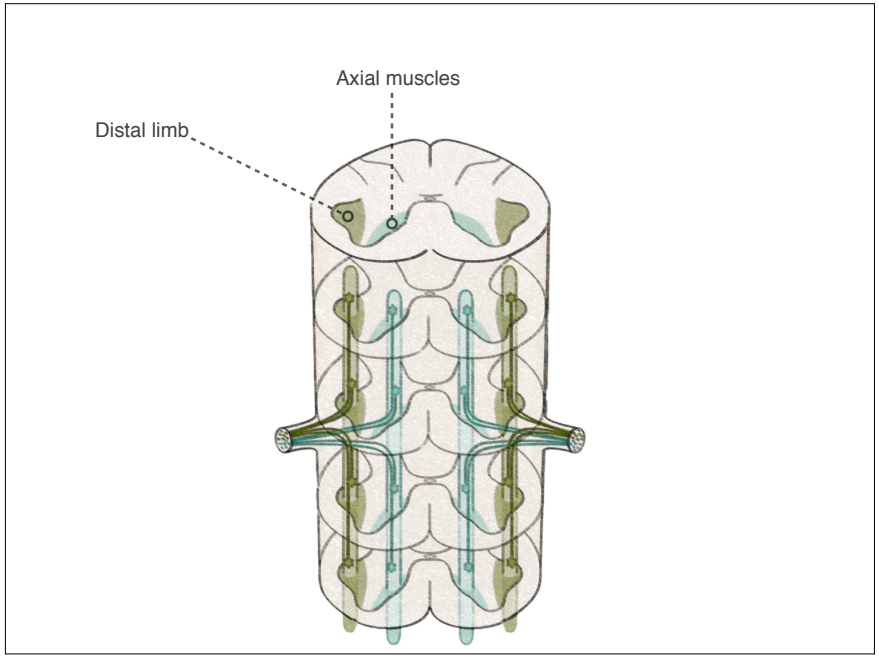
THE VERTEBRAL ARTERY

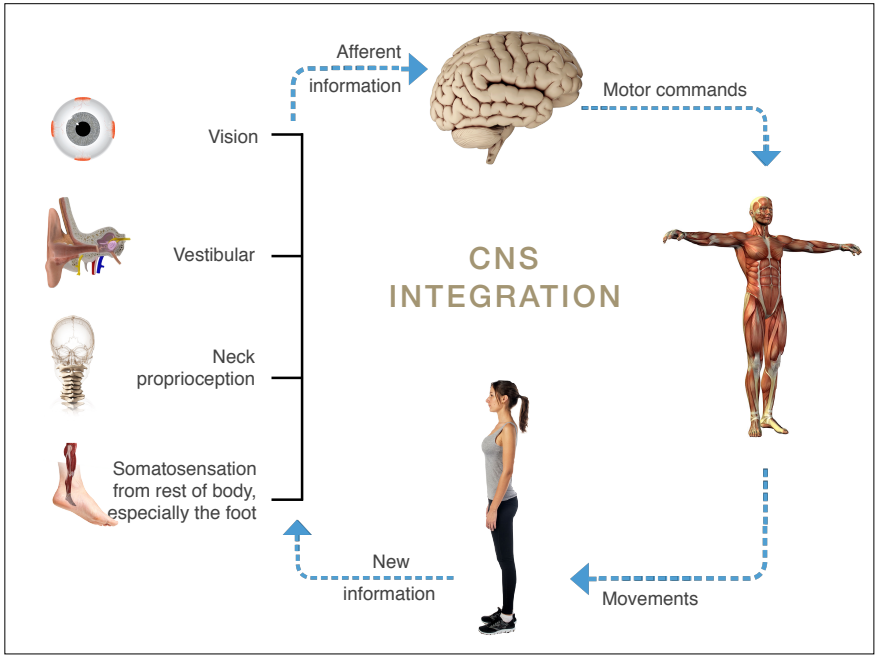
Must consider the effect of cervical motion and spondylotic hypertrophy on the V2 segment of the VA

Non-intuitive strain patterns IN V2 due to the complex fixation of the vertebral artery to the transverse foramen

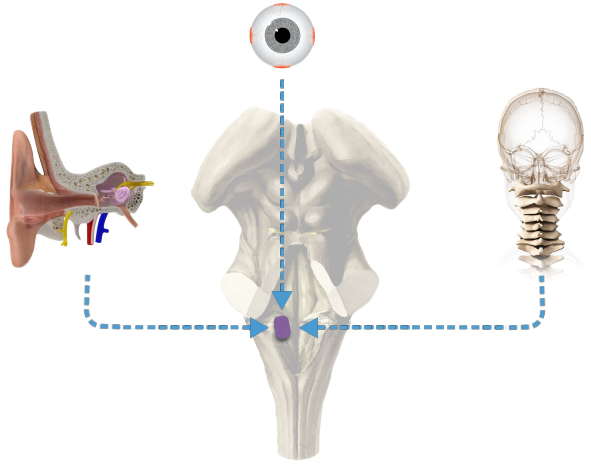
PATHOANATOMICAL LEVEL

Understanding of the role of posture and position on foraminal area, IVF pressure, and neural tension should inform the provision of targeted cervical management for patients with CDD and radicular complaints


Axial muscles
Distal limb


Afferent information
Motor commands
Vision
Vestibular
Neck proprioception
Somatosensation from rest of body, especially the foot
CNS INTEGRATION
New information
Movements

NEUROLOGY OF POSTURAL STABILITY



SENSORY ROLE OF THE DISC

Spine

SPINE Volume 42, Number 8, pp 540–546

BASIC SCIENCE

Mechanoreceptors in Diseased Cervical Intervertebral Disc and Vertigo

Liang Yang, MD,[†,‡] Cheng Yang, MD, PhD,[§] Xiaodong Pang, MD, PhD,[*] Duanming Li, MD,[*] Hong Yang, MD,[*] Xinwu Zhang, MD,[¶] Yi Yang, MD,[||] and Baogan Peng, MD, PhD[*]

“It is likely that these mechanoreceptors in normal cervical discs are involved in a proprioceptive transducer function. Indeed, as cervical discs are located in the axis of cervical spinal movements, they are in a favorable position for the accurate detection of small load or position changes...”

“If the firing characteristics of the mechanoreceptors in the diseased cervical disc are changed due to both inflammation and an increase in their number, erroneous signals will be produced. These erroneous signals will increase neck deep muscle activity, and subsequently result in muscle tension. Abnormal neck proprioceptive input integrated from the signals of mechanoreceptors in cervical discs and muscle spindles in neck muscles is transmitted to the central nervous system, and will lead to a sensory mismatch with vestibular and other sensory information, resulting in a subjective feeling of vertigo or dizziness and unsteadiness.”

Pergamon

Anxiety Disorders
15 (2001) 53–79

JOURNAL OF Anxiety Disorders

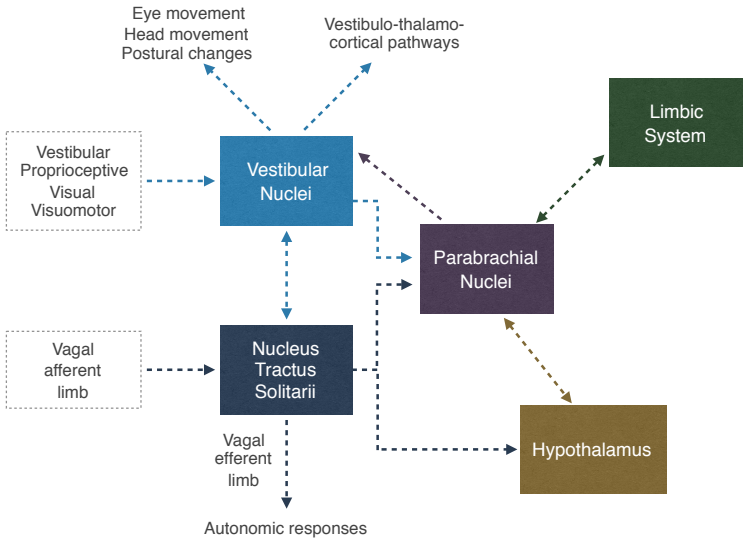
Neurological bases for balance–anxiety links

Carey D. Balaban[a,*], Julian F. Thayer[b]

[a]*Departments of Otolaryngology and Neurobiology, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA*
[b]*National Institute on Aging, USA*

"Specifically, the parabrachial nucleus is a site of convergence of vestibular information processing and somatic and visceral sensory information processing in pathways that appear to be involved in avoidance conditioning, anxiety, and conditioned fear."

BALANCE AND ANXIETY



IMPAIRED BALANCE AFFECTS COGNITIVE RESERVE

Behavioral and Brain Functions

BioMed Central

Research

Open Access

Patterns of postural sway in high anxious children

John F Stins*, Annick Ledebt, Claudia Emck, Elisabeth H van Dokkum and Peter J Beek

Address: Research Institute MOVE, Faculty of Human Movement Sciences, VU University Amsterdam, van der Boechorststraat 9, 1081 BT, Amsterdam, The Netherlands

Email: John F Stins* - j.stins@fbw.vu.nl; Annick Ledebt - a_ledebt@fbw.vu.nl; Claudia Emck - c.emck@fbw.vu.nl; Elisabeth H van Dokkum - liesjetvandokkum@gmail.com; Peter J Beek - p.beek@fbw.vu.nl

* Corresponding author

Numerous studies have found impaired balance in individuals with anxiety disorders and conversely, elevated levels of anxiety among individuals with vestibular disorders – suggesting that there is a common pathological mechanism.

It has been shown that postural sway of highly anxious children is:

1. Greater in magnitude
2. Greater in velocity
3. Less complex than typically developing children

Stins *et al* found that the anxiety group is less reliant on automatized postural control processes, and centre of pressure (COP) fluctuations were less complex compared to controls.

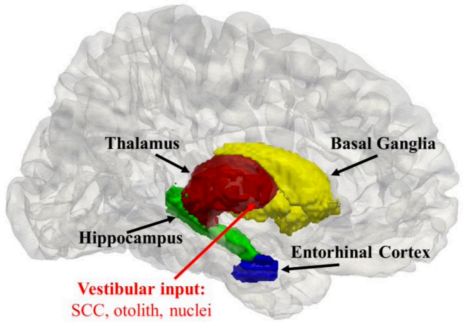
These latter two measures have been linked with the amount of attention invested in the regulation of balance

"Thus, the present findings suggest that children with elevated levels of anxiety utilise excessive attentional resources for the maintenance of posture. Under normal circumstances the regulation of balance takes place in a (nearly) fully automatic manner, which leaves the individual enough room to allocate attention to other tasks, such as talking, thinking, or visual search. Our results imply that children with elevated levels of anxiety will be less capable of dividing attention between the regulation of balance and cognitive secondary tasks."

A course of balance training involving 12 weekly sessions resulted not only in improved balance, but also in reduced anxiety and higher self-esteem in a group of children with comorbid balance disorders and elevated levels of anxiety.

Bart *et al* 2009

MAPS OF OUR ENVIRONMENT IN THE OLD BRAIN



MAPS OF OUR ENVIRONMENT IN THE OLD BRAIN

Consider the evolutionary advantages of an animal knowing where it is within its environment

Mammals have mapping neurons located in the hippocampus and *entorhinal cortex* - roughly the size of a finger in humans

MAPS OF OUR ENVIRONMENT IN THE OLD BRAIN

Place cells

Grid cells

MAPS OF OUR ENVIRONMENT IN THE OLD BRAIN

Grid cells fire at multiple locations, forming a grid pattern like the rows and columns on a paper map

Place cells fire every time the rat is at a particular location

Neck provides input to ‘head direction cells’

Spine

SPINE Volume 41, Number 11, pp E667–E673

DIAGNOSTICS

Reorganization in Secondary Somatosensory Cortex in Chronic Low Back Pain Patients

Sabina Hotz-Boendermaker, PhD, Valentine L. Marcar, D.Phil, Michael L. Meier, PhD, Bart Boendermaker, MSc, and Barry K. Humphreys, PhD

Spine

SPINE Volume 42, Number 15, pp 1172–1178

DIAGNOSTICS

Smudging of the Motor Cortex Is Related to the Severity of Low Back Pain

Siobhan M. Schabrun, PhD,*† Edith L. Elgueta-Cancino, Mphil,† and Paul W. Hodges, PhD†

"Motor cortex reorganization supports the notion that the nervous system adopts a new strategy for movement/stability with LBP. It has been hypothesized that in the presence of pain and/or injury, the nervous system implements new motor strategies to "protect the part" from further injury/ pain. This is often mediated by increased trunk muscle activity, particularly large superficial muscles, to splint the spine."

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Feeling stiffness in the back: a protective perceptual inference in chronic back pain

Received: 22 December 2016
Accepted: 27 July 2017

Tasha R. Stanton[1,2], G. Lorimer Moseley[1,2], Arnold Y. L. Wong[3,4] & Gregory N. Kawchuk[3]

There is also good evidence for an impaired representation of neck function within multiple brain regions, leading to a general stiffening motor control pattern in neck pain patients.

Meisingset *et al. BMC Musculoskeletal Disorders* (2015) 16:56
DOI 10.1186/s12891-015-0517-2

BMC Musculoskeletal Disorders

RESEARCH ARTICLE Open Access

Evidence for a general stiffening motor control pattern in neck pain: a cross sectional study

Ingebrigt Meisingset[1*], Astrid Woodhouse[1], Ann- Katrin Stensdotter[1], Øyvind Stavdahl[2], Håvard Lorås[1], Sigmund Gismervik[1,3], Hege Andresen[4], Kristian Austreim[1] and Ottar Vasseljen[1]

- Delayed onset of deep neck flexors
- Increased activation of superficial neck flexors
- Decreased flexor muscle endurance
- Decreased cervical muscle strength
- Multifidus muscle atrophy
- Lower movement velocity
- Jerky movement patterns
- Reduced trajectory movement control
- Irregular and stiffer movement patterns
- Increased postural sway
- Functional balance disturbances and dizziness
- Reduced cervical joint position sense
- Breakdown in eye movement control

The key finding was that neck pain patients show an overall more rigid neck motor control pattern compared to healthy controls - indicated by lower neck flexibility, slow movement velocity, increased head steadiness and a more rigid trajectory. Neck flexibility was the parameter that showed the significant association with clinical features in neck pain patients.

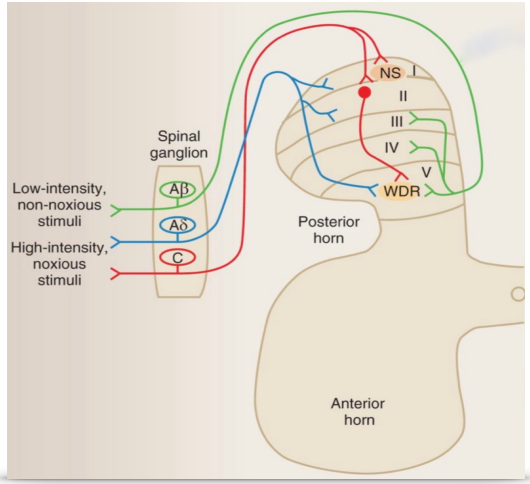
Neck pain patients may still have a full gross range of motion in a certain direction, but the conjunct movements were much more limited. There is a marked limitation in the richness of small movements.

A SMUDGED BRAIN MAP AND STIFF NECK / BACK

A MODEL FOR THE CERVICAL SPINE

- Pain as a protective behaviour
- Cortical representation (model)
- Balance, posture and sensorimotor control
- Biomechanics and pathoanatomy
- Red flags

SECOND ORDER NEURONS ARE KEY POINTS OF MODULATION



THE PAIN NEUROMATRIX

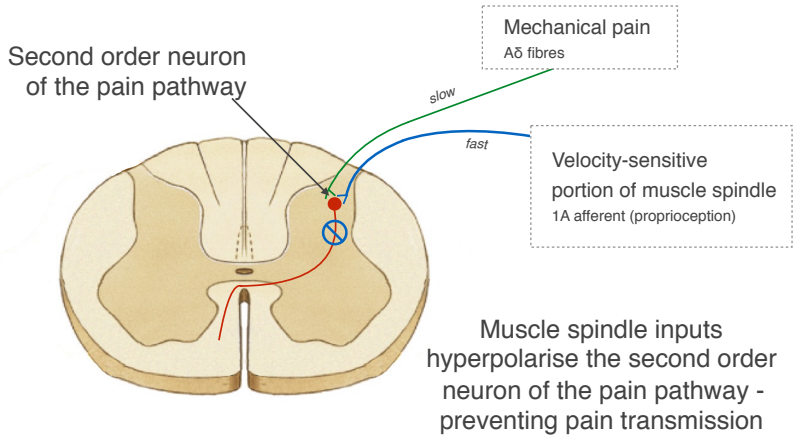
UNPLEASANT SENSATIONS
AND PROTECTIVE BEHAVIOUR

PAIN IS ABOUT MEANING

PAIN IS AN OUTPUT BEHAVIOUR

PERCEIVED NEED TO PROTECT

NOVEL SENSORY STIMULUS



HOW DO WE INFLUENCE ALL DIMENSIONS OF BOB'S PROBLEM?