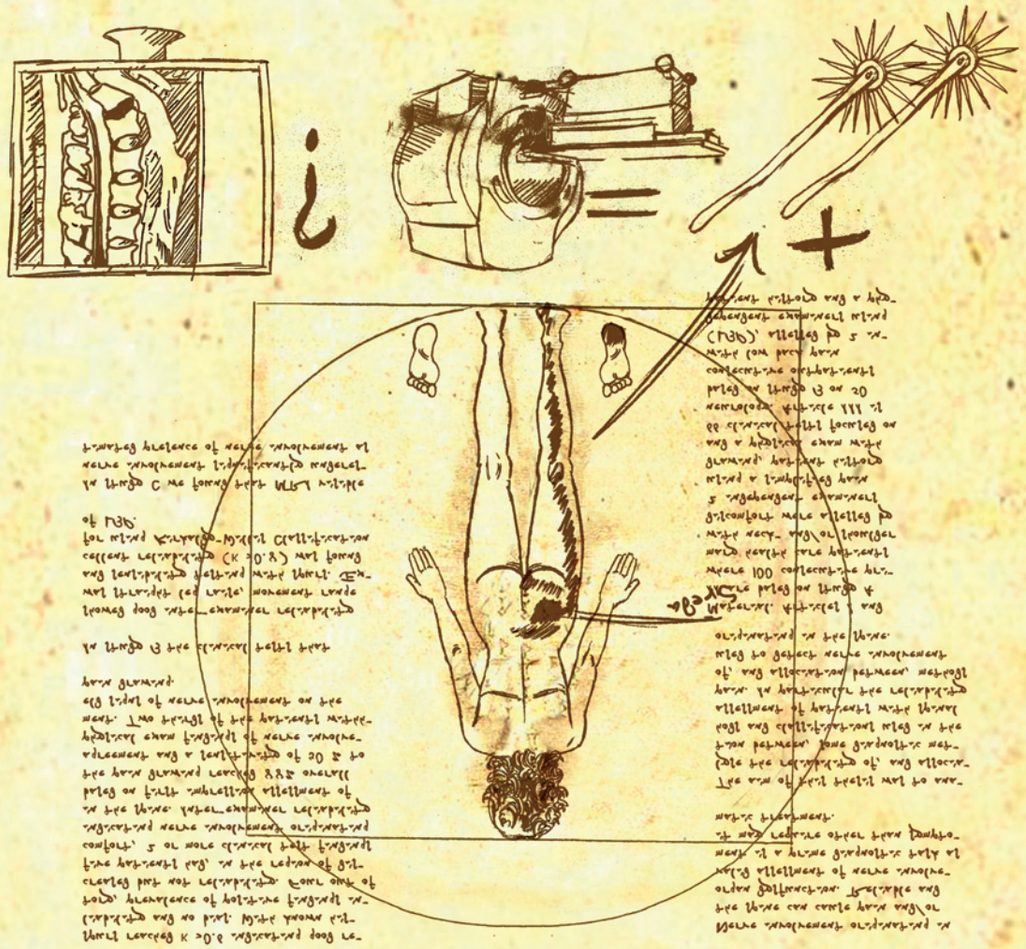
Bo C Bertilson

On the assessment of nerve involvement and of dysfunction in patients with spinal pain



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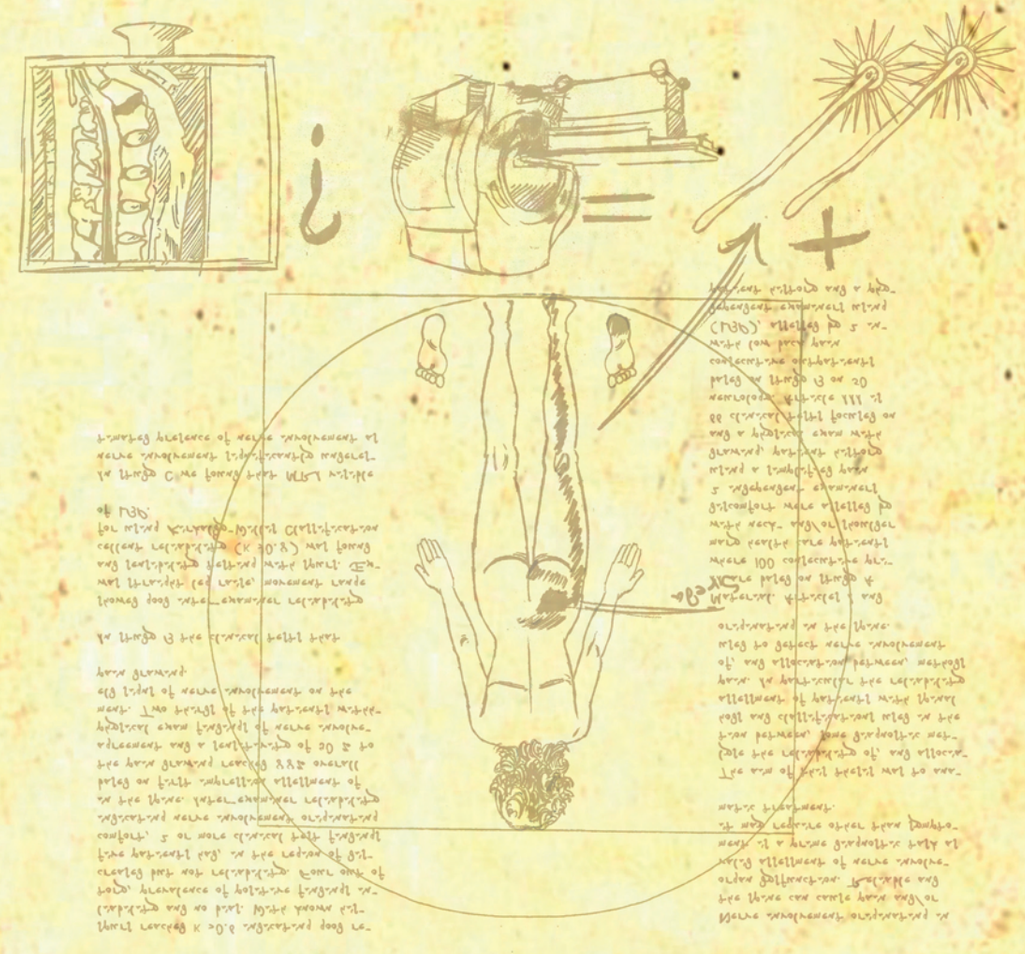

From the Center for Family and Community Medicine
Karolinska Institutet, Stockholm, Sweden

On the assessment of nerve involvement and of dysfunction in patients with spinal pain

Bo C Bertilson

Karolinska Institutet

Stockholm 2009

"The glory of God is intelligence, or, in other words, light and truth."

Doctrine & Covenants 93:36

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To my beloved wife Nancy and our precious children Michael, Eva, Marie, Marcus, Elisabet and Mattias and to my Parents for their constant love and support.

List of articles

This thesis is based on the following articles, which will be referred to by their Roman numbers.

I. **Reliability of clinical tests in the assessment of patients with neck/shoulder problems – impact of history**
Bertilson BC, Grunnesjö M, Strender LE
Spine. 2003 Oct 1;28(19):2222-31

II. **Pain drawing in the assessment of neurogenic pain and dysfunction in the neck/shoulder region: inter-examiner reliability and concordance with clinical examination**
Bertilson B, Grunnesjö M, Johansson SE, Strender LE
Pain Med. 2007 Mar;8(2):134-46

III. **Inter-examiner reliability in the assessment of low back pain (LBP) using the Kirkaldy-Willis Classification (KWC)**
Bertilson BC, Bring J, Sjöblom A, Sundell K, Strender LE
Eur Spine J. 2006 Nov;15(11):1695-703

IV. **Assessment of nerve involvement in the lumbar spine: association between magnetic resonance imaging, physical examination and pain drawing findings**
Bertilson BC, Brosjö E, Billing H, Strender LE
Submitted

Abstract

Nerve involvement originating in the spine can cause pain and/or organ dysfunction. Reliable and valid assessment of nerve involvement is a prime diagnostic task as it may require other than symptomatic treatment.

The aim of this thesis was to analyse the reliability of, and association between, some diagnostic methods and classifications used in the assessment of patients with spinal pain. In particular the reliability of, and association between, methods used to detect nerve involvement originating in the spine.

Material. Articles I and II are based on study A where 100 consecutive primary health care patients with neck- and/or shoulder discomfort were assessed by 2 independent examiners using a simplified pain drawing, patient history and a physical exam with 66 clinical tests focused on neurology. Article III is based on study B on 50 consecutive outpatients with low back pain (LBP), assessed by 2 independent examiners using patient history and a physical exam with 30 clinical tests. Article IV is based on study C on 61 consecutive patients referred to magnetic resonance imaging (MRI) of the lumbar spine where we used the simplified pain drawing, patient history and a physical exam focused on neurology to detect nerve involvement originating in the spine.

Results. In study A inter-examiner reliability was less than acceptable for many tests. Only a bimanual sensibility test with spurs reached $\kappa > 0.6$ indicating good reliability and no bias. With known history, prevalence of positive findings increased but not reliability. Four out of five patients had, in the region of discomfort, 2 or more clinical test findings indicating nerve involvement originating in the spine. Inter-examiner reliability based on a first impression assessment of the pain drawing reached 88% overall agreement and a sensitivity of 90 % to the final assessment. Two thirds of the patients added symptoms to the pain drawing during history session.

In study B excellent inter-examiner reliability ($\kappa > 0.8$) was found for using Kirkaldy-Willis Classification of LBP. Radiological findings had no impact. Good inter-examiner reliability was found for straight leg raise, movement range and sensibility testing with spurs.

In study C we found that MRI visible nerve involvement significantly underestimated the high percentage of nerve involvement detected in the physical exam and in the pain drawing.

Conclusions. Nerve involvement can be detected reliably, simply and quickly with a bimanual sensibility test with spurs and a pain drawing. MRI visible nerve involvement in the lumbar spine underestimates presence of nerve involvement detected in a physical exam and a pain drawing. Nerve involvement in both the cervical and lumbar spine may be a greatly underestimated cause of pain and/or organ dysfunction. This may explain part of today's poor treatment outcome of spinal pain and should encourage further studies on diagnostics and treatment of nerve involvement originating in the spine.

Abbreviations

CNS	Central Nervous System
CT	Computer Tomography
IASP	International Association for the Study of Pain
κ	Cohen's Kappa value or Kappa coefficient
KWC	Kirkaldy-Willis Classification
LBP	Low Back Pain
MRI	Magnetic Resonance Imaging
PD	Pain Drawing
PET	Positron Emission Tomography
PHC	Primary Health Care
PNS	Peripheral Nervous System
PSLR	Passive Straight Leg Raising
ROM	Range Of Motion
SBU	The Swedish Council on Technology Assessment in Health Care
SIJ	SacroIliac Joint
VAS	Visual Analogue Scale
WHO	World Health Organization

Contents

A drama in the emergency ward

by Lars Johan Leidholm (with permission)

So it happened one evening, a far away guest in our country got the address wrong and, though completely healthy, entered the hospital emergency ward. Unfortunately he did not know the language. He spoke only guttural sounds like "ohoho" and "semaama" while swinging his arms and looking happy.

The reception staff professionally freed him from his coat and a bag with personal belongings. An interpreter could not be found, but based on his behaviour, the staff assumed the patient had stomach ache. This meant that the surgeon was first in line for the "sell the patient game" as the true Total Quality Management spirit gave the specialists a chance to give each patient a well-founded and diversified assessment.

Surgeon: "mentally disturbed homeless with appendicitis?" on paper in the file: abdomen soft and substantially adipose, splashing bowel sounds. Nothing surgical, but may try laxative. Looks a little red and warm, infection consultant.

Infection doctor: no neck stiffness, CRP normal, nothing for us, but possibly lice in the beard and appropriate treatment proposed. Cardiac decompensation or silent infarct? Has to go to medicine

Internal medicine consultant: lungs clear, ECG normal, no internal medicine case, though may be diuresed with 40 mg Furosemide. Probably expressive aphasia, obvious neurology case.

Neurologist consultant: neurological status WNL and CT of the brain normal but suggest Trombyl 75mg x1. Referral to the nearest psychiatric clinic, given the odd behaviour. Subclinical acute delirium? Medical certificate attached.

Psychiatrist: strikingly dressed and apparently an expansive personality with hysteroinfantile features, however no obvious need for closed psychiatric care. Neurobion injections cannot hurt considering suspicious alcohol habitus. Looks a little red in the eyes, acute glaucoma? Ophthalmologist case.

Treated with laxatives and diuretics, filled with vitamins and having a bunch of yellow slips named “prescriptions”, our acknowledged good-natured patient began to lose patience, but wasn’t able to find his way out of the windowless emergency ward maze. Was caught by the ophthalmologist who found: free media, but perhaps a little conjunctivitis. Gets prescription for eyedrops. Seems - despite diuresis - a little out of breath. Respiratory insufficiency, silent asthma? Has to go to the lung clinic.

Lung specialist: hyperresonant to percussion, but normal blood gases and normal PEF. May well have some emphysema, recommend stopping smoking. Has anyone thought about epiglottitis, given the mushy speech? Ask ENT to check the throat.

The ENT consultant was rescued by the child Kalle with sore ears who was on his way from ENT and who - with big round eyes - met our good-natured patient. Kalle said astonished: What are YOU doing here? I have been a good boy all year and you have not been at our home yet. Come along and I will show you where I live.

So in the end all went well and Kalle got his Christmas gifts after Santa signed a receipt to get his bag back.

Introduction

Like Santa Claus in the previous story, patients with spinal pain all too often seems to wander through a never ending line of specialists, tests, treatments and multidisciplinary rehabilitation centres without a specific diagnose and without getting better – at least not in their own opinion (49, 51). This intriguing fact has been imposed on my mind day by day and year by year as I have received patients with unclear spinal pain and dysfunction on referral for examination and treatment.

From these examinations, treatments and my continuous search for knowledge I distil three main motives why I started this thesis work;

1. A discrepancy between common notions about patients with spinal pain and my personal observations.
2. A cry for help from numerous patients suffering from spinal pain.
3. A call from society for effective diagnostic methods and treatment of patients with spinal pain.

A discrepancy between common notions about patients with spinal pain and my personal observations

Common notions

A common notion about patients with spinal pain is that it is non-specific and that clinical findings and nerve involvement are rare (5, 73, 122). Radiological findings in patients with spinal pain are often called 'degenerative', 'non-significant' or 'age dependent' and notion holds that radiological findings are seldom correlated to the patient's pain or dysfunction (122). However MRI is considered to have high sensitivity but low specificity in the diagnostic process to detect nerve involvement (122). Other notions about patients with spinal pain are that they are tense or have weak muscles that need to be stretched or trained. Also that they are psychosocially distressed and that this give rise to or at least adds to their suffering. Furthermore that they are unwilling or less motivated to work (77, 140). Consequently, they should be treated with cognitive therapy and/or antidepressant medicines and not sick listed.

A general notion and much promoted recommendation in Sweden is that neck and back pain is self limiting and disappears within a few weeks if only one keep up daily activities (147). In the conclusion of the last report on back and neck pain the Swedish Council on Technology Assessment in Health Care (SBU) states that *"…for most patients with back trouble the PHC measures are the only needed."* In the next sentence it states that *"...one of the most important tasks of the PHC physician is not to intervene unnecessarily. The risk of exposing the patient for meaningless examinations and treatments without scientific foundation is …that the patients back problem develops into chronic and lifelong trouble."* This statement may – to some – sound like a notion 'don't touch the patient'.

Personal observations

My personal subjective observations are based on a process including diagnostic testing, treatment and follow up of tens of thousands of patients with spinal pain. In the diagnostic testing I have consistently used a structured clinical exam with special focus on the detection of possible nerve involvement originating in the spine. For the past two decades this structured clinical examination has included assessment of a simplified pain drawing with a visual analogue scale as part of the history, followed by a physical exam including a thorough neurological exam, palpation of the spine and testing of different organ functions.

The thorough neurological exam has included assessment of hypotrophy and other visible signs of dysfunction, reflexes, sensibility

testing and testing of muscle strength. The sensibility testing has been made bimanually and included sensibility to touch and pain and often also other modalities of sensibility. The main method to test sensibility to pain has been the use of two spurs drawn slowly over indicator areas of the skin.

In a large number of cases the findings and diagnoses based on the clinical exam have been compared with radiological findings, mainly plain, and MRI scans that I personally assess. Radiological scans and assessments have many times been repeated with some years in between.

Diagnostic injections to block specific nerves or joints along the spine have been part of my daily clinical work.

From this process the following observations have been made;

1. Patients with spinal pain very often have clinical findings, including signs of nerve involvement, indicative of injury to specific segments of the spine, – signs often unnoticed by the health care system.
2. The simplified pain drawing can show patterns of nerve involvement originating in the spine, especially when the patient is asked to give a full account of all symptoms
3. Patterns of nerve involvement assessed in the pain drawing are often in agreement with findings in a thorough physical exam.
4. Nerve involvement originating in the spine is often manifested as dysfunction in the sclerotome, viscerotome and/or myotome area of the respective nerve before symptoms of spinal pain arise. Such dysfunctions are often diagnosed as separate entities or diseases.
5. Radiological findings differ depending on the radiologist.
6. Following trauma to the spine, radiological findings develop slowly over time, though discoligamentous injuries can be predicted by findings in the pain drawing and physical exam long before they are radiological visible.
7. MRI visible nerve involvement in the spine seems to underestimate the presence of clinical findings of nerve involvement originating in the spine.
8. Even slight radiological signs of pathology in spine may be correlated to patient's symptoms.
9. Stretching and strength training with axial loading of the spine is often pain provoking in patients with clinical nerve involvement.
10. Psychosocial distress may diminish if patient receives an understandable explanation to their symptoms by someone who has won their trust. This trust depends much on the thoroughness of the physical exam – the 'touch of the patient'.
11. Unwillingness to work is rare among these patients – they do want to work and play and live a full life. A great majority of these patients do work in spite of their pain.
12. Spinal pain and dysfunction due to nerve involvement is not self limiting but has a tendency to spread from one segment of the body to another with time, especially in patients with neck injuries.
13. Spinal pain and dysfunction due to nerve involvement does not disappear, not even in years, but patients who feel that they are not understood or examined by the physician do disappear from their clinic. However they do continue to seek other health care providers often to great personal costs.
14. Spinal pain, dysfunctions and psychosocial distress promptly disappear when nerve involvement is found and treated/abolished.

These personal observations presents a discrepancy to common notions about patients with spinal pain and motivated me to start this thesis work to find out if there is any scientific substance in some of my observations.

A cry for help from numerous patients suffering from spinal pain

In Sweden, an astounding 63% of the adult population (16-84 years of age) – experience pain in the neck, shoulder, back or joints according to the report from Statistics Sweden in 2006 (125). Females dominate this pain statistics with 2.5 million (71%) but also 2 million men (58%) experience this type of pain totaling 4.5 million persons! Of these, 1.4 million experience severe pain. The most common site of pain is the neck-shoulder area, especially among women (125). Spinal pain is the main reason for long standing suffering and inability to work (125).

I have seen only a very small part of these millions of patients. Yet, over the years I have met and examined tens of thousands of them – most of them with chronic pain and dysfunction – and the cry for help seems very similar whether they come from near or far.

As a new patient enters my room I look at their pain drawing and quickly begin the thorough physical exam. However, I do use at least one question – Why do you come to me? Or – What do you expect? At this question, often 3 "want" and 3 "don't want" crystallises.

The want;

1. What is it that hurts? No one seems to know! The explanation – the diagnosis.
2. What is the future of my pain? The prognosis.
3. What can be done to alleviate the pain? The treatment.

The don't want;

1. Pills – "Painkillers, antiepileptic, , antidepressant etc …I´ve had it all."
2. Talk – "No more psychosocial rubbish…I´ve been through it all."
3. Sick leave – "I want to work and play and interact with family and friends as before."

The following results from a survey by Gunilla Brattberg, performed some years ago on chronic pain patients, to a large extent coincide with my own (24).

The cry for help from patients with unresolved spinal pain presents a strong motive to seek for better assessment methods especially for those with unnoticed nerve involvement.

Figure 1. *'Importance' of different care procedures according to patients and care personnel,*

** indicates statistically significant difference, 0 = unimportant, 100 = very important. (Translated and depicted with permission from Gunilla Brattberg)*

A call from society for effective diagnostic methods and treatment of patients with spinal pain

Former Swedish minister of finance, Kjell-Olof Feldt, declared in 1990 *"…we do not have the economy for anything else than effective diagnostics and treatment … all else is inhumane…"* (38).

Effectiveness in diagnostic decision-making is mandatory in all aspects of medical service. However, this call for effectiveness in the medical care of musculoskeletal conditions is especially in focus during what by WHO has been proclaimed 'the bone and joint decade' (year 2000 to 2010).

In January 2000, WHO Director General Dr Gro Harlem Brundtland declared, "*While the diseases which kill take much of the public attention, musculoskeletal or rheumatic diseases are the major cause of morbidity throughout the world. These diseases have a substantial influence on health and quality of life, and they inflict an enormous cost on health systems*" (27).

The cost for pain related disorders in Sweden has been estimated to about 90 billion crowns (121) The absolute majority (90%) of these costs were related to sick-listing. Then, what can be done to save some of this money?

A man with knowledge and vision in the field of medicine, professor Lars Werkö, uttered, "*The greatest savings that can be achieved in medical services lie in the possibility of reaching a correct diagnosis as soon as possible in a state of illness*" (personal communication).

Concerning the diagnostic process, Nachemson and Vingård in a SBU report on back and neck pain notes that there is a remarkable lack of evidence base for basic diagnostic methods: *"Despite …an increase in neck syndromes during the past decade…not many studies describe in detail the precision and usefulness of the history and the physical examination*". They underline the importance to detect central nerve involvement, so called red flags (123).

The diagnostic process of LBP is considered difficult due to a lack of knowledge about its origin. Only 5-15% of cases are said to have a specific diagnosis (123). The rest are classified as 'non-specific' LBP, where psychosocial factors are often stressed (18, 56, 142, 144). An accurate and reproducible classification of LBP has been identified as the top priority for primary care research (21). Fritz et al may well be correct in asserting that "*Identifying relevant subgroups of patients could improve clinical outcomes and research efficiency*" (41).

Jensen adds to the call for evidence based effective diagnostic methods and classifications of spinal pain in routine clinical practice with the observation that, *"A major criticism of the reported research body for spinal pain is that no consensus exists on what and how to assess…just as health care providers previously used treatment without really knowing the effect until evidence-based medicine was introduced, so methods of examination and assessment whose clinimetrical properties have not been determined still are used in clinical practice"(59).*

The call from society for added knowledge about effective diagnostic methods among patients with spinal pain has further motivated this thesis work.

Aims

Overall aim

The overall aim of this thesis was to analyse the reliability of, and association between, some diagnostic methods and classifications used in the assessment of patients with spinal pain. In particular the reliability of, and association between, methods used to detect nerve involvement originating in the spine. By this we hope to add some knowledge that will help to more effectively diagnose and treat patients with spinal pain and dysfunction.

Specific aims

Study A

Article I

1. To evaluate inter-examiner reliability of clinical tests in the assessment of discomfort in the neck/shoulder region in primary care patients.
2. To evaluate impact of history on the reliability of clinical tests and prevalence of positive findings in the above-mentioned patient category.

Article II

1. To evaluate inter-examiner reliability in a first impression assessment of the simplified pain drawing concerning neurogenic pain/dys-function in the neck/shoulder region.
2. To evaluate the process of learning how to use the simplified pain drawing in the assessment of neurogenic pain/dysfunction.
3. To evaluate concordance in the assessment of nerve involvement between the first impression assessment of the pain drawing and a final assessment based on the complete clinical exam.
4. To evaluate how often patients add to or delete information from the simplified pain drawing as they receive further instruction.

Study B

Article III

1. To evaluate inter-examiner reliability in classifying patients with low back pain according to Kirkaldy-Willis Classification (KWC).
2. To evaluate impact of knowledge of radiological findings on the KWC.
3. To evaluate inter-examiner reliability in clinical tests in the assessment of low back pain.

Study C

Article IV

To evaluate association between magnetic resonance imaging visible nerve involvement and findings of nerve involvement detected in a structured physical examination and a simplified pain drawing.

Summary of studies

Study A - article I and II

I *Reliability of Clinical Tests in the Assessment of Patients with Neck- Shoulder Problems – Impact of History*

II *Pain Drawing in the Assessment of Neurogenic Pain and Dysfunction in the Neck/Shoulder Region: Inter-Examiner Reliability and Concordance with Clinical Examination*

This was a diagnostic clinical study on patients seeking help in the primary health care system for discomfort in the neck- and/or shoulder region.

In article I a first aim was to evaluate inter-examiner reliability of clinical tests. A second aim was to evaluate impact of history on the reliability of the clinical tests and prevalence of positive findings.

In article II a first aim was to evaluate inter-examiner reliability in a first impression assessment of the simplified pain drawing concerning neurogenic pain/dysfunction in the neck/shoulder region. A second aim was to evaluate the process of learning how to use the simplified pain drawing in the assessment of neurogenic pain/dysfunction. A third aim was to evaluate concordance in the assessment of nerve involvement between the first impression assessment of the pain drawing and a final assessment based on the complete clinical exam. A fourth aim was to evaluate how often patients add to or delete information from the simplified pain drawing as they receive further instruction.

Material and methods

Two examiners independently assessed 100 consecutive patients using a self-explanatory simplified pain drawing (filled out by the patient in the waiting room), patient history and a physical exam with 66 clinical tests focused on neurology. Randomisation decided if the patient was to be assessed first by the use of the physical exam or the pain drawing and also which examiner to begin with (Figure 2).

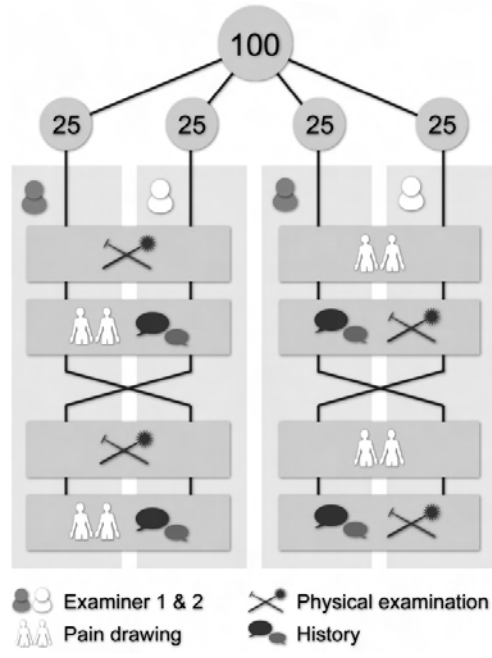

Figure 2. *Study flow in study A.*

Subsequently all patients were examined by both examiners with a complete clinical exam where, during the history session, they were asked if they had any further discomfort than what they had initially noted on the pain drawing. A final assessment based on both examiners complete clinical exam was also made.

As only one of the examiners was familiar with the assessment of the simplified pain drawing, a training session was held prior to the inclusion of the actual study patients. Also two evaluation sessions on the assessment of the pain drawing were held one third and two thirds into the study.

Inter-examiner reliability was calculated as percent agreement and with kappa statistics. Concordance between first impression assessment of the pain drawing and a final assessment was calculated as sensitivity.

Results

In article I we note that inter-examiner reliability was poor or fair (κ <0.4) in many clinical tests. Only a bimanual sensibility test with spurs reached kappa values indicating good reliability. With known history, prevalence of positive tests increased but not the inter-examiner reliability. Bias was apparent in all test categories except the sensibility test. Four out of five patients had, in the region of discomfort, two or more clinical test findings indicating nerve involvement originating in the spine.

In article II we note that inter-examiner reliability based on a first impression assessment of the pain drawing reached 88 % overall agreement and a sensitivity of 90 % to the final assessment. Two thirds of the patients added symptoms to their pain drawing during the history session.

Conclusions

In article I we conclude that some common tests used in the assessment of discomfort in the neck/shoulder region may not be reliable. However, our bimanual sensibility test showed good inter-examiner reliability and was also exempt from bias and should be studied further. History had no impact on inter-examiner reliability but increased the prevalence of positive findings indicating a need for history.

In article II we conclude that first impression assessment of the simplified pain drawing seems to be a reliable, easily learned and sensitive diagnostic method for assessing nerve involvement in the neck/shoulder region. However, as patients tend to withhold symptoms when they fill in the pain drawing we recommend that during the history session they be asked to tell the whole truth about their discomfort as this may add clues to the origin of their discomfort.

A common conclusion based on the results noted in both articles is that nerve involvement originating in the spine seems to be a very common – and may be a greatly underestimated – cause of discomfort in the neck/shoulder region. We recommend that patients with discomfort in the neck/shoulder region be screened for nerve involvement originating in the spine with the simplified pain drawing, and a neurological exam including the bimanual sensibility test with spurs.

Study B - article III

III *Inter-examiner reliability in the assessment of low back pain using the Kirkaldy-Willis classification (KWC)*

This was a diagnostic clinical study with a first aim to evaluate inter-examiner reliability in classifying patients with low back pain according to KWC. A second aim was to evaluate influence of radiological findings on the KWC. A third aim was to evaluate inter-examiner reliability in clinical tests in the assessment of low back pain.

Material and methods

Two examiners independently assessed 50 consecutive outpatients with low back pain. Assessment tools were a history interview and a structured physical exam with 30 clinical tests commonly used in the everyday work at the clinic. Radiological examination results were asked for in the history interview. Randomisation decided which examiner to begin with (Figure 3).

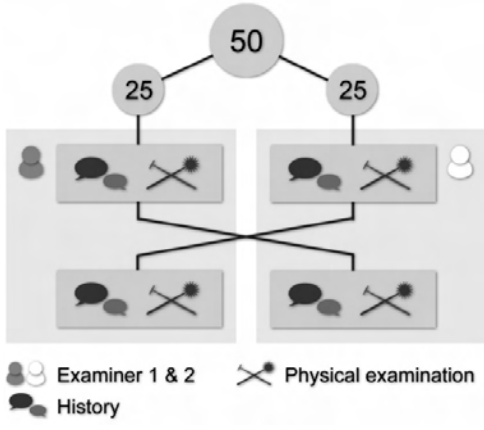

Figure 3. *Study flow in study B.*

For each patient, the examiner had to decide which of the three phases (I-III) in the KWC the patient was in. Also, when radiating pain was present the examiner had to decide whether there was nerve root involvement or not.

Inter-examiner reliability in the assessment of KWC phase and clinical tests was calculated as percentage agreement and with kappa statistics.

Results

Inter-examiner reliability was excellent ($\kappa > 0.8$) for classifying patients with low back pain according to KWC. Knowledge of radiological findings had no impact on the KWC. Age of the patient, movement range, pain and neurological signs seemed to guide the classification.

Good inter-examiner reliability was found for straight leg raising test, some movement range tests and sensibility testing with spurs in different dermatomes. About half of the clinical tests reached kappa values indicating acceptable reliability and the other half did not.

Conclusions

The KWC of low back pain may be a reliable pathoanatomic classification system depending on a few key observations. The straight leg raising test, some movement range tests and sensibility testing with spurs in different dermatomes may be recommended for use in the assessment of low back pain.

Study C - article IV

IV *Assessment of nerve involvement in the lumbar spine: association between magnetic resonance imaging, physical exam and pain drawing findings*

This was a diagnostic study with the primary aim to evaluate association between magnetic resonance imaging (MRI) visible nerve involvement and findings of nerve involvement detected in a structured physical examination and a simplified pain drawing.

Material and methods

Sixty-one consecutive patients referred to MRI of the lumbar spine were assessed for nerve involvement with a simplified pain drawing, a history interview, a structured physical exam and the MRI (Figure 4).

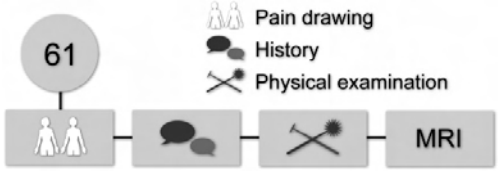

Figure 4. *Study flow in study C.*

Association between findings of nerve involvement was calculated as overall agreement, the p value for McNemar´s exact test, specificity, sensitivity and positive and negative predictive values.

Results

MRI visible nerve involvement was found in 49% of the patients while it was detected in the structured physical examination and the simplified pain drawing in 57% to 95% of the patients depending on the diagnostic test. MRI visible nerve involvement was significantly less common than and showed weak association with physical exam and pain drawing findings of nerve involvement in corresponding body segments. Mean sensitivity of MRI visible nerve involvement, in segment L4-5 where most findings of nerve involvement were detected, to a positive neurological test in the physical exam ranged from 16-37%. Mean specificity of MRI visible nerve involvement, in segment L4-5, to a positive neurological test in the physical exam ranged from 61-77%. Positive and negative predictive values of MRI visible nerve involvement in segment L4-5 to a positive neurological test in the physical exam ranged from 22-78% respectively 28-56%.

Conclusions

MRI visible nerve involvement significantly underestimated the high percentage of nerve involvement detected in the physical exam and in the pain drawing on patients referred to lumbar MRI.

Other factors than visible nerve involvement – on the MRI – may be responsible for findings of nerve involvement in the physical exam and the pain drawing.

The use of a structured physical exam and a simplified pain drawing is recommended in the assessment of low back pain. This procedure may reveal that many patients with `MRI invisible` lumbar symptoms are in need of treatment aimed at nerve involvement.

Neuroanatomic considerations

The human nervous system consists of the central (CNS) and the peripheral (PNS) nervous system. The CNS consists of the brain and spinal cord. The PNS consists of cranial and spinal nerves that connect the brain and spinal cord to the rest of the body. The nervous system and the spine are closely connected. The CNS is surrounded by the bone-skull and the spinal cord by the vertebral column – the spine – which serves as a shield for the spinal cord (Figure 5).

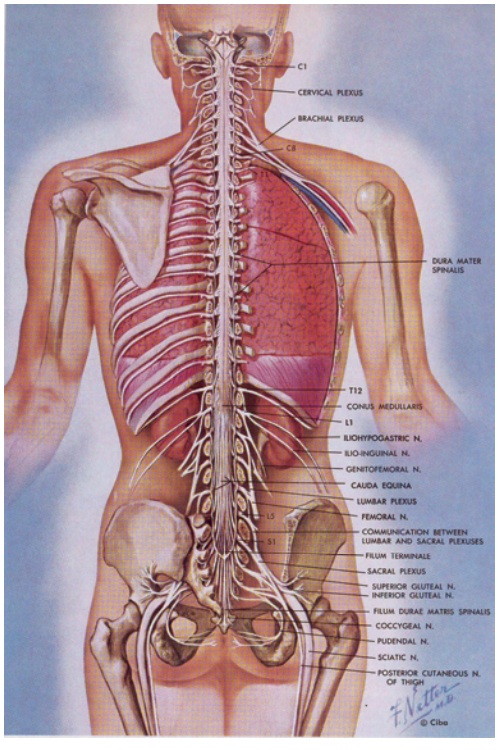

Figure 5. *The spinal cord in the spine.*

Spinal nerves emerge from the spinal cord in pairs and leave the protecting spine through lateral holes (foramen) at each vertebral level. After passing through the foramen the spinal nerve is divided into smaller branches (Figure 6).

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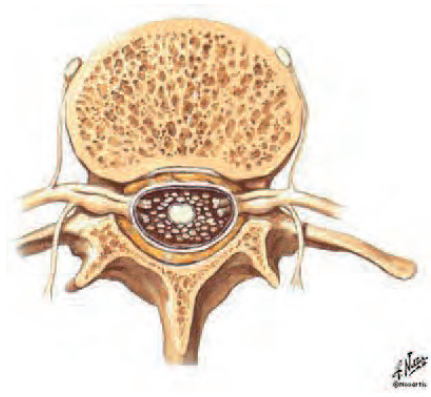

Figure 6. *Spinal nerves emerging through foramina in a vertebra.*

Nerve branches reach out into the body to transmit impulses between the CNS and all organs (Figure 7).

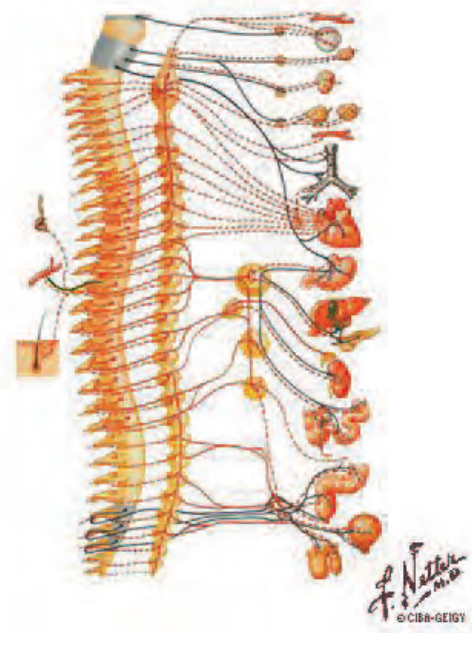

Figure 7. *Innervation of organs.*

Figure 5, 6, 7 and 11 from the Ciba Collection of Medical Illustrations, volume I, the Nervous system.

Nerve injury

Injury to a nerve may result in pain and/or organ dysfunction. A central injury like stroke or multiple sclerosis may cause wide-spread pain and/or dysfunction (47). Trauma to the PNS may cause local pain/dysfunction but also secondary central sensitisation (9, 10, 136).

The close relation between the CNS and the spine and is like a two edged sword. The spine protects the CNS from direct trauma, infection, heat and many forces. However, severe injury to the spine such as a luxation/listhesis or acute herniation of a disc (Figure 8) may result in spinal cord injury. Such injuries are easily diagnosed with radiographic methods.

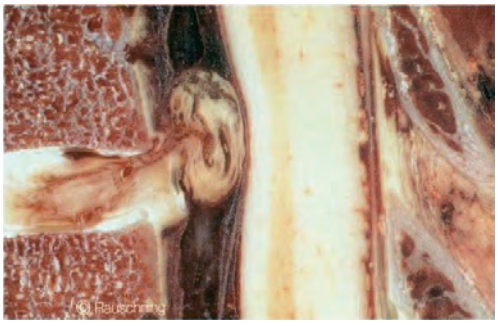

Figure 8. *Herniated disc. Slide from Dr. Wolfgang Rauschning, with permission.*

More subtle damage to the spine can result in discoligament injuries that may or may not at first cause nerve involvement (139). Such injuries may not be visible on any radiologic screen (63). Yet, with time (years) posttraumatic spondylarthrosis including degeneration of a disc and growth of osteophytes may cause spinal and/or foraminal stenosis with increasing nerve involvement and debilitating symptoms (Figure 9) (67, 76).

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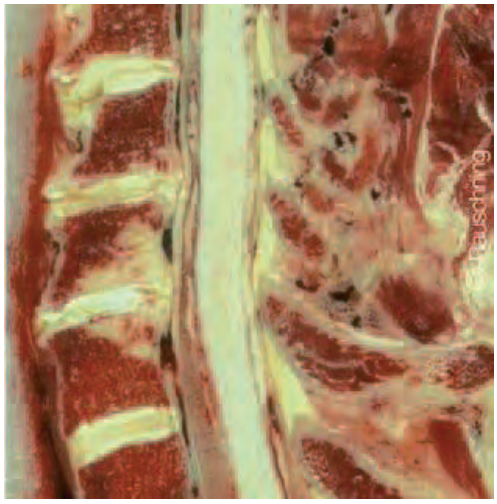

Figure 9. *Posttraumatic spondylarthrosis. Slide from Dr. Wolfgang Rauschning , with permission.*

Other nerve injury mechanisms include bio-chemical and other inflammatory agents that may be released from injured discs (101, 102, 118). Also, traction forces on the sensitive spinal nerve rootlets (Figure 10) can result in injuries not visible on MRI or other scans but may be detected by meticulous physical examination (76).

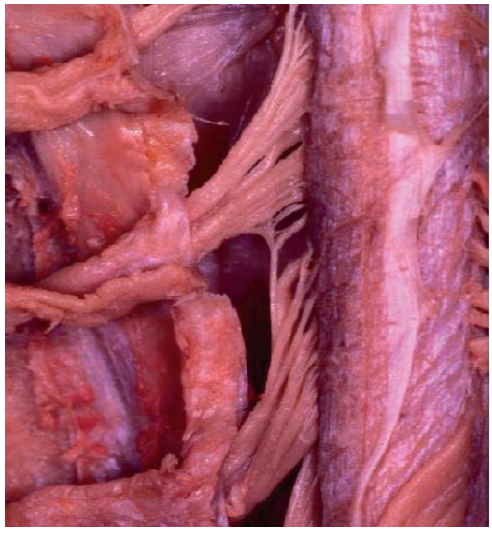

Figure 10*. The C4 and C5 ventral rootlets.Slide from Dr Nobuhiro Tanaka, Hiroshima University, with permission.*

Neuropathic pain – definition

Pain initiated or caused by a primary lesion or dysfunction in the nervous system has been termed neurogenic or lately more commonly neuropathic. In article I and II we used the term neurogenic, however to adhere to present nomenclature suggested by IASP we now use the term neuropathic.

The discovery of central sensitisation by neuroplasticity to nociceptive input has prompted a redefinition of neuropathic pain (135, 136). In 2008 the following definition suggested by Treede et al was accepted by IASP: "*pain arising as a direct consequence of a lesion or disease affecting the somatosensory system" (136).*

Neuropathic pain – detection

To diagnose neuropathic pain and/or dysfunction at least two criteria has to be fulfilled. First, a neuroanatomical distribution of the pain/dysfunction.

Second, evidence of sensory dysfunction involving a peripheral nerve or plexus (48). If the affected nerve or pathway is mixed motor and sensory then weakness, muscle atrophy, or reflex abnormalities may be additional clues to nerve involvement (8, 48). In addition, verbal descriptors has proved to be sensible screening tools to detect nerve involvement (11).

The use of a pain drawing and careful neurologic examination, including testing of sensory functions has by Hansson been suggested as the basis for assessment of nerve involvement. *"A pain drawing made by the patient frequently gives a good indication of the neuroanatomic distribution and quality of the pain. Impaired sensation is often evident during a careful examination. Sensory dysfunction may be manifested as hypo- and/or hyperesthesia for one or more modalities, increasing pain to normally painful stimuli (hyperalgesia) or pain due to normally nonpainful stimuli (allodynia)"* (47, 48).

Assessing neuroanatomic distribution of pain/dysfunction is easily done if the patient draws all his/her discomfort on the pain drawing and the clinician know the neuroanatomy of the body. This includes knowledge of the innervation of the skin (dermatomes), muscles (myotomes), bone (sclerotomes) and the inner organs (viscerotomes).

In our studies we have used the dermatome chart suggested by Netter to assess neuroanatomic distribution on the pain drawing and also to assess the sensibility test in the physical exam (Figure 11).

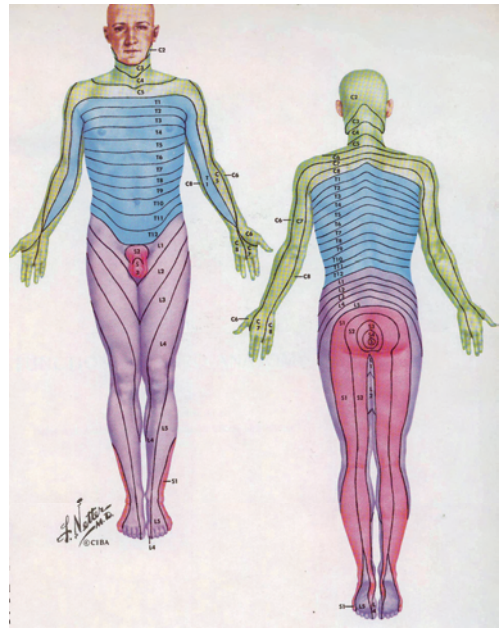

Figure 11. *Dermatome chart by Netter.*

Analytic considerations

In our studies we dichotomised most findings to become a matter of a yes or no, positive or negative finding. This was done in order to simplify the analysis and increase the number of findings in each category. Our data are therefore mainly nominal data. These data are dependent data due to the fact that assessments, whether they were done by different examiners or with different diagnostic methods, were done on the same patient.

As we assess agreement between findings done by different examiners or methods there are properties and measures of agreement that need to be considered.

Properties of agreement

Assessments of patient conditions should optimally be not only cost- and time-effective and non-harmful but first of all reliable and valid. Otherwise, the assessment cannot be recommended for clinical use. Reliability and validity are properties of agreement between assessments, examiners and diagnostic methods.

Reliability

The reliability of a diagnostic method is defined as the degree of stability exhibited when an assessment is repeated under identical conditions. Inter-examiner reliability refers to how well two examiners agree on an assessment using the same diagnostic method.

Validity

The validity of a diagnostic method is defined as the extent to which an assessment, a measurement, test or study measures what it purports to measure. In other words, validity is the degree of agreement or concordance of the measurement or other result of examination with a certain criterion – a golden standard. The criterion for what is to be measured must therefore be defined for each test.

Reliability does not imply validity and validity does not imply reliability. A dart table with darts close to each other in a certain spot may exemplify good reliability. However, if the darts are not near the centre or the place where they were supposed to be (the criterion) the validity is poor (Figure 12a).

Figure 12a. *High reliability, low validity.*

Darts dotted around the centre may exemplify good validity but poor reliability (Figure 12b).

Figure 12b. *High validity, low reliability.*

Darts dotted close to each other in the centre may exemplify good reliability and validity (Figure 12c).

Figure 12c. *High validity and reliability.*

Measures of agreement

Between examiners

Agreement may be expressed as **percentage of agreement** on the criterion. This is easily understood but does not take into account the agreement that may result from chance alone. For categorical data it is therefore preferable to calculate a Kappa value when we want to express the reliability of a certain test.

Kappa value (Kappa coefficient) (κ) was defined by Cohen in 1960 in order to adjust for agreements due to chance alone. It can range from 1 to –1, with a value of 1 indicating perfect agreement and values lower than 0 indicating less than chance agreement.

The interpretation of κ values between 0 and 1 is as follows: 0-0.2 poor, 0.21-0.4 fair, 0.41-0.6 moderate, 0.61-0.8 good and > 0.8 very good (4). Instead of very good, some authors use the expression excellent (65, 96), which is the term used in this thesis. A method or assessment reaching $\kappa > 0.4$ is considered acceptable (45, 132).

The formula for $\kappa = (p0 - pe)/(1- pe)$.
In this formula p0 stands for the observed frequency of agreement in percent and pe the expected frequency of agreement in percent.

The weakness of κ is that it is influenced by the prevalence of positive findings and is attenuated severely towards low values when prevalence is either particularly low or high (143). Therefore, κ should not be calculated when the mean of the examiner's prevalence is below 10% or above 90% or when the prevalence of one examiner is 0% (132). Some suggest that κ is too unstable already at the 85% level (45). In our studies the 90% level is used.

Between a method and a gold standard

The agreement between assessments made by means of a diagnostic method and its criterion, the gold standard, may be expressed in percentage as overall agreement, sensitivity, specificity**,** and positive and negative predictive values.

The formulas for estimating these measures are depicted in Figure 13.

Overall agreement is the proportion of samples where the test and the golden standard agree on the criterion whether it is a positive or a negative result (a+d/a+b+c+d).

Sensitivity is the ability of a test to classify as positive those samples with the criterion in question (a/a+c).

Specificity is the ability to classify as negative those samples without the criterion in question (d/b+d). Sensitivity and specificity make up the validity.

To distinguish statistical sensitivity from the neurological test procedure - sensitivity to pain – which we used in our studies, the word sensibility is used for the neurological test procedure in all articles except number I where it is termed sensitivity.

Positive predictive value is the proportion of samples with positive test results that are correctly diagnosed (a/a+b).

Negative predictive value is the proportion of samples with negative test results that are correctly diagnosed (d/c+d).

Predictive values, unlike sensitivity and specificity, depend on the prevalence of the abnormality we test for.

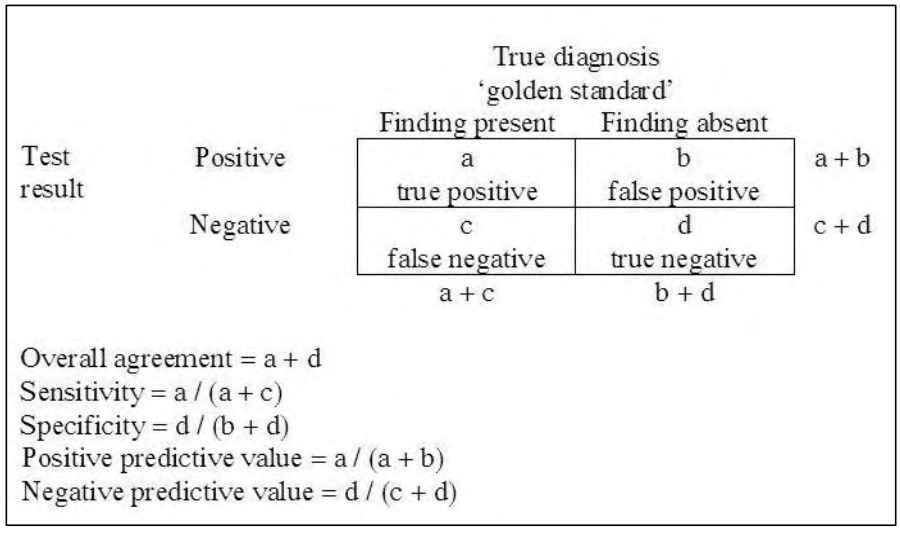

Figure 13. *Estimating measures of agreement between a diagnostic method and a golden standard.*

Diagnostic considerations

To diagnose is to recognize (as a disease) by signs and symptoms a disease or condition in the patient (90).

History of spine diagnostics

The model to diagnose spinal symptoms has changed over time. Until the mid-19th century each patient seemed to be a **unique case** (144).

In 1841 a report by Valliex who found disc protrutions on autopsy initiated a **biomedical model** to diagnose spinal pain (112). This model, based on pathoanatomical findings, drove spine care science for over a century (144). Yet, only a minority of patients with spinal pain or dysfunction received and still receives a specific – clear pathoanatomic – diagnosis (19).

In 1977 Engel proposed a **biopsychosocial model** aimed at psychiatric disease. This model was quickly adapted into the spine care community and has come to reign sovereign at the throne of spine care in the western society (42, 144). Wadell in 2006 notes: *"It is now widely recognized that spinal pain and disability can only be understood and managed according to a biopsychosocial model"* (141).

However, accurate diagnostics and successful treatment of spinal pain remain equally elusive today as before (31, 37). One must ask: If the diagnostic model is right then why do we not get better results in the spine care community? (49).

The force of the diagnosis

The diagnosis has a force in itself inasmuch as it is used socially to confer/reject acceptability to patient behaviour; to justify health policy decisions; to structure medical relationships; to shape medical/ institutional infrastructure; to direct patient care via guideline establishment; and to manage health care (144).

A specific diagnosis may lead to a more specific and effective treatment to free the patient from pain and/or dysfunction and also from the burden of uncertainty.

A clear diagnosis – a clear explanation to the cause of their pain – is the prime expectation of patients with spinal pain as they seek help (89, 145).

Dissatisfaction with explanations for spinal pain may be related to superficial clinical management and/or lack of knowledge about what diagnostic methods may and may not be appropriate to use – the evidence base of the method (89, 127, 145).

Diagnostic methods of the spine – evidence base

Diagnostic methods are used to investigate the origin of the patient´s pain and/or dysfunction. Common methods used to assess spine problems are clinical, radiological, and laboratory examinations and diagnostic blocks.

Clinical examination methods

Clinical examination methods include history taking and a physical exam. History taking may or may not include a pain drawing and visual analogue scale (VAS). The physical exam includes clinical tests of various kinds.

History taking and a physical exam are considered the most important sources of information in the diagnostic process (43). Yet, few studies support this idea.

In the clinical setting, history taking usually precedes the physical exam and thus may determine its form, thereby influencing the diagnostic procedure itself. To our knowledge, the possible influence of history taking on physical exam findings on patients with spinal pain and/or dysfunction has not been addressed in previous studies.

History taking

Previous studies on the reliability of history taking in patients with dysfunction in the low back region show varying results. Vroomen et al found when assessing lumbar nerve root involvement that consistency in diagnosis increased from κ 0.40 to κ 0.66 when history was added to the physical exam (157).

Leclaire et al found that the diagnostic accuracy of even experienced clinicians was less than chance when history and physical exam were assessed on simulators of back pain (74).

Michel et al found in a study on the association between clinical findings in the physical exam and self-reported severity of back pain a relatively weak agreement between the physical exam and history (91). We find no report on the reliability of history taking in the assessment of the neck/shoulder region.

In our studies we have used both pre-determined questionnaires and free questioning in the history taking process. Only some of the basic characteristic data from this process is included in our articles so far.

Pain drawing (Figure 14)

The first published article on the pain drawing was presented in 1949 by Palmer who described characteristic patterns in the pain drawing as signifying either organic or nonorganic pain. Since then a number of studies have been conducted on this topic mainly to discern organic from non- (or in-) organic pain, more commonly referred to as functional or psychogenic pain, the results have been controversial (53, 84, 107).

Ransford et al in 1976 designed a penalty point scoring system for the pain drawing with the purpose to identify back pain patients with psychological problems. They found that patients with unusual pain patterns (especially marks made outside the body drawing) also tended to have elevated scores on the hysteria and hypochondriasis scales (114).

Von Baeyer et al, later, in a study on 212 patients with back pain concluded that "*Pain drawings cannot validly be used in this way, since over half of the patients meeting...criteria for psychological involvement in their pain were incorrectly identified as normal on the pain drawing*" (156). Brismar et al agreed (26).

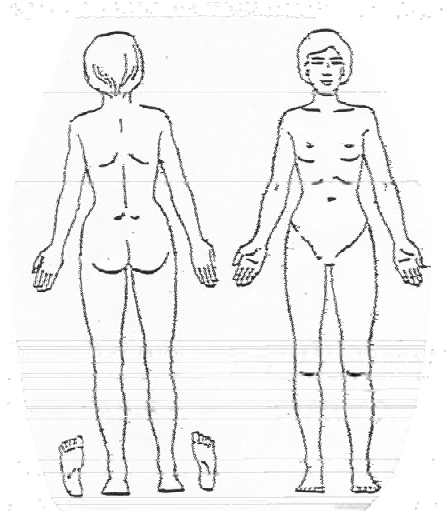

Figure 14. *The pain drawing.*

Uden and Landin in 1987 presented another idea of how to assess the pain drawing. Their main idea was to use it to assess nerve involvement (138).

Vucetic et al and Ahlbeck later found good correlation between pain drawing patterns and level of disc disease found at lumbar spine operation (2, 158).

Studies on reliability of pain drawings divided into different numbers of body areas have been published, with most of them indicating good inter-examiner reliability (28, 84, 85).

Ohnmeiss in 2000 reported that patients were consistent in completing the pain drawing on occasions separated by a relatively long period of time. She concluded that the pain drawing is a stable instrument for use in patients with chronic back pain (97).

Rankin et al in a study on assessment of nerve root compression in the lumbar spine found that the pain drawing was not a good predictor

of MRI visible nerve compression and that it should be interpreted with caution and in light of the full clinical picture (113).

Other studies on the pain drawing report the method to be quick and simple, yet reliable and sensitive with good validity in assessing nerve involvement originating in the low back region (12, 98-100, 137).

Tanaka et al in 2006 report specific pain patterns in the neck/scapular region for cervical nerve roots relieved at operation (134). The study by Tanaka et al is the only study we find that consider the idea of pain patterns in the neck/shoulder region as possible predictors of nerve involvement in the cervical spine. Our study A was by then closed but our observations to a large extent coincide with those of Tanaka et al as indicated in article II.

In our studies we use a simplified pain drawing with the intention to differentiate between nociceptive, psychogenic and neuropathic patterns of discomfort. For this purpose the drawing has been called 'Drawing of discomfort'. The simplification is that the patient shades, with a lead pen, all areas of the body drawing where they experience discomfort of any kind. No special marks for pain ache, stabbing or other qualities of pain are to be used. Our hypothesis is that shading instead of cluttering the drawing with special marks help visualise a possible neuroanatomic distribution pattern.

Visual analogue scale (VAS)

The VAS is a simple method for rating pain or dysfunction with a mark on a straight line with the endpoints of 0 and 10 or 0 and 100, with zero indicating no pain or dysfunction and 10 or 100 indicating worst conceivable pain or dysfunction. Studies on patients with spinal pain or dysfunction have reported that VAS ratings show a good correlation with other more complicated devices for measuring disability such as the Pain Disability Index and similar questionnaires (44, 68, 79, 104, 148).

Physical examination

Numerous studies assess reliability of clinical tests in the physical exam of patients with spinal pain. Most studies deal with motion or pain, few assess nerve involvement.

Clinical tests in the examination of the neck/shoulder region

Assessment of motion or movement has shown acceptable reliability for **passive general motion** (39, 143). Assessment of **passive intervertebral motion** and **joint-play** has shown unacceptable reliability (39, 93, 129).

Palpation for tender structures has shown similar reliability figures. **Zygapophyseal joint pressure** pain has show slight-to-fair agreement (143). **Tender points** have shown agreement ranging from "not better than chance" to "substantial agreement (132, 143). Maximal cervical **spine tenderness** has shown good inter-examiner reliability (54).

Neurological tests for cervical spine

Studies on assessment of nerve involvement are less common. Assessment of upper body **muscle strength** has shown unacceptable reliability (40). The **foramen compression test** has shown good reliability (132).

The study reported by Viikari-Juntura in 1987 still seems to be the most complete study on tests used in the assessment of the cervical spine. She found good reliability in **atrophy inspection** of the small muscles of the hand, in the **sensibility** tests for touch and pain, and in the **neck compression and axial manual traction** tests. Fair reliability was obtained in muscle strength testing and in assessing range of motion. Poor reliability was obtained for many palpations. Poor standardisation of examination procedures and changes in the patients' attention were considered the main factors affecting reliability (150).

In study A we included the most reliable tests found by Viikari-Juntura in our structured physical examination protocol. Figure 15 shows the test procedure of some of our clinical tests.

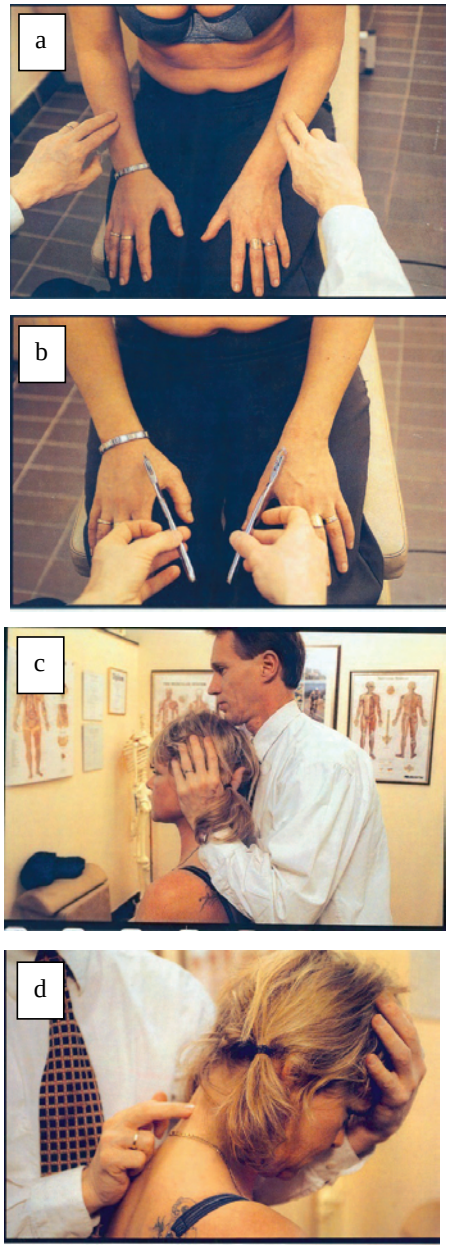

Figure 15. *Clinical tests in study A.*

a. palpation of tender points
b. test of sensibility to touch
c. test of sensibility to pain
d. neck traction test

Clinical tests in the examination of the low back region

Studies on the assessment of **range of motion**, **muscle stiffness and/or joint mobility** mainly show unacceptable reliability (52, 72, 83, 88, 106).

Sacroiliac joint (SIJ) tests have been studied more than most tests. Poor to acceptable reliability has been found (29, 32, 111). However, Dreyfuss et al in a study on the 12 best SIJ tests found that *"none of the 12 tests, and no combination of these 12 tests, demonstrated worthwhile diagnostic value"* (36).

Palpation for tender structures has shown reliability figures ranging from poor to moderate (83, 94, 95).

The reliability of assessing length of **muscles and other somatic findings** was investigated by Saur et al in 1996. They concluded that assessment of Schober sign, lumbar flexion, fingertip-to-floor measurements, straight leg rising of the left leg, and lengths of both legs were almost perfectly reliable while length of the iliopsoas and the rectus muscles exhibited a lower reliability (120).

May in a review article 2006 concluded that *"Most procedures commonly used by clinicians in the examination of patients with back pain demonstrate low reliability"* (87).

Neurological tests for lumbar spine

Studies on clinical tests assessing nerve involvement originating in the lumbar spine are rare. Strender et al found almost a 100% agreement on neurological tests (passive straight leg raising, sensibility, muscle strength and reflex tests). However, the prevalence of positive findings for the tests was too low to allow the calculation of κ (133).

The exception to the lack of studies on clinical tests assessing nerve involvement is studies on the **passive straight leg raising** test (P/SLR) which, mentioned above, has shown good reliability (120, 133) . However, Rebain et al in a review of the passive straight leg raising test

as a diagnostic aid for low back pain conclude; *"There remains no standard PSLR procedure, no consensus on interpretation ... The causal link between LBP pathology and hamstring action remains unclear. There is a need for research into the clinical use of the PSLR; its intra- and interobserver reliability; the influences of age, gender, diurnal variation, and psychosocial factors; and its predictive value in lumbar intervertebral disc surgery"(116)* .

Radiologic examination methods

These methods include scans like plain (X-ray), computer tomography (CT), myelography, magnetic resonance imaging (MRI) including functional (kinetic) MRI and positron emission tomography (PET). In our studies plain X-ray and conventional (non-kinetic) MRI scans have been used. Only MRI scans have been assessed by our study personnel and will be commented on.

Magnetic resonance imaging (MRI)

MRI, or nuclear magnetic resonance imaging (NMRI), has been in use for a little more than 30 years (X-ray over 110 years). Unlike X-ray and CT scans MRI uses no ionizing radiation but a magnetic field to align hydrogen atoms in the body. The method provides detailed images of the body in any plane and with great contrast between different tissues of the body. This property makes it especially useful in assessing neurological and musculoskeletal structures of the body.

Reliability of MRI visible spinal structures

Studies have shown variable reliability for different structures and segments of the spine.

Reliability in cervical spine

Studies on the reliability of MRI visible cervical spine structures are less common and seem less conclusive than studies done on lumbar MRI findings (22, 33, 55)**.**

Reliability in lumbar spine

Inter-examiner reliability in assessing **herniated discs** of different kinds has shown fair to good reliability (58, 80, 109). Assessment of spinal **stenosis** has shown good reliability while assessment of foraminal stenosis and nerve root impingement has shown moderate reliability (81).

Studies on the assessment of other structural pathologies in the lumbar spine has included the presence of **bright facet** response, **osteophytes**, **spondylolisthesis**, **facet arthropathy**, **disk degeneration**, **endplate (Modic) changes**, and **high signal intensity zones (HIZ).** Acceptable to good agreement by expert examiners has been shown (30, 61, 78, 110). A comment by Jarvik and Deyo on the latest study on such MRI visible structures may summarise the present status on reliability: "*The readers were experts in spine imaging—the crème de la crème. In spite of these advantages, they achieved, for the most part, only moderate interobserver agreement, with κ values of 0.44–0.59. The one exception was the interobserver agreement for rating disk degeneration, for which the κ was 0.66"*(57).

Association between MRI visible spinal structures and spinal pain and dysfunctions

For years the prevailing hypothesis has been that **herniated discs** or other space limiting factors, causing nerve impingement, are the origin of spinal pain. Studies have yet to prove this.

In the cervical spine disc and ligament injuries - **discoligament injuries** – have been associated with various clinical symptoms and signs and is an area for much studies (17, 22, 55, 64, 69, 70, 92). The most consistent association between MRI visible findings and clinical signs has been found between soft lateral cervical disc prolapse and Spurling's test (126, 151).

In the lumbar spine, only severe disc extrusion with nerve compression has predicted pain distal to the knee (12). Disc bulges, protrusions

and other space limiting structures has been found among people without low back pain and are presently generally considered non-symptomatic (16, 20, 60).

The association between clinical findings and MRI visible structures other than space limiting structures has come into focus in the 1990s. Such structures include Modic changes and HIZ (Figure 16).

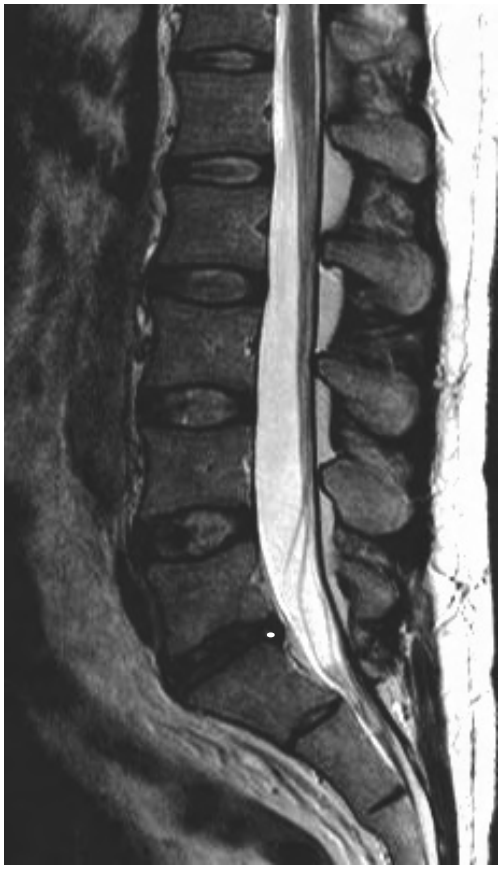

Figure 16. *MRI of lumbar spine with small HIZ posterior in disc L5-S1.*

The presence of a HIZ has been correlated to the presence of grade 4 annular disruption and with reproduction of the patient's pain. Its sensitivity as a sign of pain is low but the its positive predictive value for a symptomatic disc has been found to be as high as 86% in one study, yet only 40% in another study (6, 130).

Functional (kinetic) MRI recordings were reported by Willen et al in 1997. Such MRI recordings are gaining interest as they may explain more of the MRI invisible spinal pain and dysfunction (152, 153, 159). The reliability and validity of these methods need to be studied further.

Discussion

The answer to our aims presents some new, clinically interesting and somewhat challenging results.

In study A we assessed patients with discomfort in the neck/shoulder region. We found less than acceptable inter-examiner reliability for many clinical tests. Only a bimanual sensibility test with spurs showed good inter-examiner reliability and no bias. With known history prevalence of positive clinical tests increased but not inter-examiner reliability. Four out of five patients had, in the region of discomfort, two or more clinical test findings indicating nerve involvement originating in the spine.

Good inter-examiner reliability was found for first impression assessment of the simplified pain drawing concerning nerve involvement even though two thirds of the patients added symptoms to the pain drawing during history session. We found that the process to learn to use the pain drawing was easy.

In study B we assessed patients with low back pain. We found KWC to be a reliable pathoanatomic classification system not dependent of radiological findings. Sensibility testing with spurs showed good inter-examiner reliability. Many other clinical tests showed less than acceptable reliability.

In study C we assessed patients referred to MRI of the lumbar spine. We found that MRI visible nerve involvement significantly underestimated the high percentage of nerve involvement detected in the physical exam and in the pain drawing.

Strengths and limitations of our results

Less than acceptable inter-examiner reliability for many clinical tests in assessment of cervical and lumbar dysfunction

This result is not new as explained in the previous chapter on diagnostic considerations. It rather strengthens the objectivity of our studies and gives credibility to the few more reliable tests that we found. Many clinical tests we used may be of questionable value unless they can be better standardised.

Good inter-examiner reliability for the bimanual sensibility test

To our knowledge, the good inter-examiner reliability of the bimanual sensibility test represents the first scientific report on this test. Earlier textbooks and studies do not seem to consider using two spurs, one in each hand, to assess pain sensibility in dermatome indicator areas.

The bimanual sensibility test, where we had no common experience (examiner B used the bimanual method while examiner M used one spur) prior to study A turned out to be the single most reliable clinical test. This test also showed the least difference in prevalence of positive findings (no bias). This suggests that education was not the determining factor. Rather, we believe that the good reliability of this simple clinical test depends more on how easy it is to perform in a standardised manner.

A limitation to our result is that we did not have any sample of people without symptoms. Also more examiners and comparison with other diagnostic methods of nerve involvement may be used in future studies. If this test proves valid then, it may constitute an answer to the call for a “quick, practical cost-effective” sensibility test (13, 14).

Knowledge of history increased prevalence of positive findings

Our observation that prevalence of positive findings increased significantly with known history in six out of ten of our sensibility tests and in four other tests is new and clinically interesting.

Our hypothesis is that patients overlooked slight differences during the 'blinded' physical exam (where we had no knowledge of history). During the physical exam where we had knowledge of history we may have questioned their response and asked again if there was a difference in areas where we could expect it. This hypothesis is supported by the fact that the mean prevalence of all sensibility tests increased with knowledge of history, from 36 to 50%, as also their mean κ, from 0.57 to 0.67.

A limitation to the generalisation of our result is that clinical examinations are often done with shorter time limits than we had in our study. However, in clinical practice the pain drawing may be done in the waiting area as also some of the history taking. If the pain drawing and/or history give reason to suspect nerve involvement, we should not hesitate to perform the test more than once (it only takes a few seconds) and ask the patient to be very specific in his/her response.

A high percentage of patients had symptoms and signs of nerve involvement in the area of discomfort

In study A, four out of five patients had, in the area of discomfort, two or more clinical test findings indicating nerve involvement originating in the spine. In study C, similar figures were noted. These results contrast the notion that discomfort in these areas are due to tense or overused muscles or psychosocial distress. Consequently, one may question our observations.

First, the reliability of the clinical tests with high prevalence of positive findings. In study A, the sensibility to pain test and Speurlings neck compression test were both positive in about 60% of the patients. In study C, the motor function test and the sensibility to pain test were positive in at least one myotome/dermatome area in about 80% of the patients. The bimanual sensibility to pain test and Speurlings test were found to be the most reliable tests with knowledge of history and the sensibility to pain test also proved no bias. Speurlings test has by others been found to be a highly specific test but with a sensitivity of about 30% (151). From these facts we assume that the percentage of observed nerve involvement in our sensibility, neck-compression and motor tests are valid for our study populations.

Second, our study populations – were they selected segments of patients with radiculopathy not representative of open care patients? In study A, the primary health care units were repeatedly reminded to refer all consecutive patients seeking help for neck- and/or shoulder problems according to the pre-set criteria. Our impression is that they did so, and that the study population was representative of patients seen in the primary health care. In study B, all patients were consecutively entered into the study by referral from the open care system.

If nerve involvement is so common in areas of discomfort one may ask if so called tense and stiff muscles trigger and tender points, shoulder tendalgia and similar problems in reality are symptoms of nerve involvement originating in the spine. This hypothesis is supported by the observation that the signs of disturbed sensibility in the C4 - C7 dermatome areas were the same areas in which patients noted symptoms on the pain drawing. Furthermore, in about 80% of the patients there was palpable tenderness in the segment of the spine where these nerves originate (C4 - C7).

Further studies will have to elaborate on this interesting hypothesis.

Good inter-examiner reliability for the simplified pain drawing in assessment of nerve involvement

Our study may be the first to consider the use of a pain drawing to detect nerve involvement in the cervical region and also the first on the use of a simplified version of the pain drawing. Earlier studies on the standard pain drawing have shown good to excellent inter-examiner reliability in assessment of low back pain (84) and in detecting nerve involvement from specific disc levels in the lumbar spine (2).

Our observation of good inter-examiner reliability in assessing nerve involvement in the cervical region by a first impression assessment of the simplified pain drawing was made even though two thirds of the patients withheld symptoms from the initial pain drawing. Later, during history session, many patients added symptoms to the pain drawing that made nerve involvement more obvious.

An example of this 'hold back phenomena' is a patient that at the initial pain drawing shaded symptoms in the neck, shoulders, the left lateral elbow and wrist and hand (Figure 17a). During the history session this same patient added several symptoms in response to the repeated question if the drawing contained the whole truth (Figure 17b).

The observation that a majority of patients withhold symptoms on the pain drawing contrasts the notion that patients exaggerate symptoms of pain and dysfunction.

When we asked patients why they did not give a full report of their symptoms from start the answer was usually one of three: "I did not think it had anything to do with my problem" or "Doctors usually don't have time to listen to more than one problem at the time" or "I don´t want the doctor to think I am crazy". Similar comments have been noted by others when assessing patients in pain (160).

Consequently, in the process to assess the pain drawing it is important to repeatedly ask the patient to shade all areas of discomfort – not just pain – as this will make it easier to assess eventual neuroanatomical distribution of symptoms.

The foremost limitation to our results on the pain drawing is the small number of patients without nerve involvement (4 out of 50 in study A and 3 out of 61 in study C). This fact makes it difficult to calculate measures of agreement (like predictive values) with appropriate statistical power.

Our hypothesis that the pain drawing may be used to assess nerve involvement originating in the cervical region as well as from the lumbar region seems reasonable though further studies have to confirm it (134).

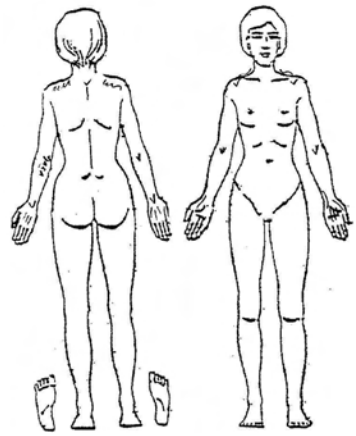

Figure 17a. *Initial pain drawing.*

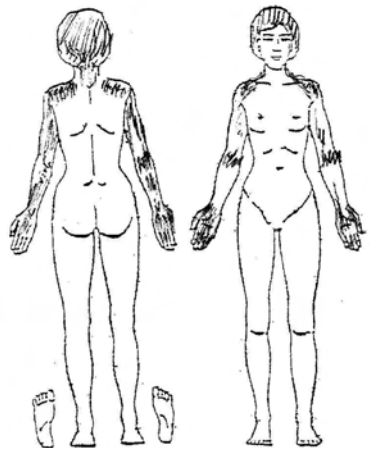

Figure 17b. *Pain drawing after repeated questioning to tell the whole truth.*

KWC a reliable pathoanatomic system for classifying low back pain

To our knowledge this is the first study to evaluate the KWC of patients with low back pain. We found excellent inter-examiner reliability similar to the best results from earlier studies on classification of low back pain (41, 65).

Classification systems of spinal pain and dysfunction has been identified as a research priority to help evaluate and standardise treatment (21). Systems have been developed based on presence/absence of nerve involvement, perceived pathoanatomy (15, 35), duration of symptoms or work status (131), or impairments linked to treatment options (35, 41, 155). Radiological and laboratory methods for classification also exist (58).

A treatment-based system has been proposed as being the most desirable (35, 155). The most common of these systems is the McKenzie system. In 1990 Kilby found a 57% agreement on classifying according to the McKenzie system while Riddle and Rothstein's study in 1993 yielded only a 39% agreement (117). Later studies on this method have concluded that the use of patterns of pain response to repeated end range spinal test movements is good and statistically significant when performed by properly trained therapists (65, 115).

A treatment based classification was, seriously questioned by Jensen et al in an investigation on patients with spinal pain (59). They found that "*no acceptable agreement was found between any of the expert's ratings of patient's needs and potential for rehabilitation*". Logistic regression showed that the expert's judgements were based almost solely on the age of the patient. Prediction analyses showed that the most consistent predictor of the patients' status at the six month follow-up assessment was the patient's own belief in the existence of effective treatments and their perceived ability for learning to cope with the condition.

We consider a pathoanatomic system including assessment of nerve involvement more adequate to guide treatment. The KWC proposed by Kirkaldy-Willis is such a system based on symptoms, signs and radiological findings (Figure 18) (66).

A limitation to our result is that all symptoms and signs described in the KWC were not verified in our study and radiological findings had no impact on the classification. Rather, the age of the patient (same as noted by Jensen (60), neurological observations and inter-segmental mobility seemed to have had most impact on the classification. The increase in mean age with subsequent diagnostic phases is in accordance with the theory of progressive degeneration in an injured segment of the spine (1, 67, 75, 105).

Further studies with treatment follow up will have to show if the KWC is a classification system that do improve the care of patients with spinal pain.

Phase	I Dysfunction	II Unstable	III Stabilisation
Symptoms	localised, sometimes referred	those of dysfunction, giving way of back: "catch"	less low back pain
	movement painful	pain on coming to standing position after flexion	mainly leg pain
Signs	local tenderness	abnormal movement	muscle tenderness
	muscle contracted, hypomobility, extension painful	observation of "catch", sway or shift when coming erect after flexion	stiffness, reduced movement, scoliosis
	seldom neurology		some neurology
Radiological changes	abnormal decreased movement	anterioposterior: lateral shift, rotation, abnormal tilt	enlarged facets
	spinous processes malaligned	malaligned spinous processes, oblique: opening facets	loss of disc height, osteophytes
	irregular facets	spondylolisthesis (in flexion), retrospondylolisthesis (in ext.)	small foramina
	early disc changes	abnormal opening of disc, abrupt change in pedicle height	reduced movement, scoliosis
		disc bulging	

Figure 18. *Key observations in the phases of the KWC system.*

MRI visible nerve involvement significantly underestimated nerve involvement detected in the physical exam and pain drawing

This result is new and challenges the notion of MRI as a very sensitive diagnostic method (124). However, there are several factors that may explain a poor association between MRI visible nerve involvement and clinical findings of nerve involvement.

First, the reliability and validity of our clinical methods to detect nerve involvement may be questioned even though we performed studies specifically aimed at this. Earlier studies on pain drawing patterns indicative of nerve involvement have come to variable conclusions (2, 12, 99, 158). For this purpose we added a thorough physical exam focused on detection of nerve involvement to be part of our assessment. However, a golden standard method to detect nerve involvement is yet to be found (46, 71, 119, 146).

Second, the inter-examiner reliability among the radiologists may be questioned and is a matter of further studies (23, 80).

Third, the reading of the MRI does not take into account the supine position of the patient in the MRI camera. Most patients do experience more pain and dysfunction in an upright position, possibly due to increased pressure on spine structures or other changes that may cause shrinking of free nerve space (62, 82, 154, 159).

Fourth, other factors than MRI visible pressure on nerves may be responsible for findings of nerve involvement in the physical exam and the pain drawing.

Olmarker and Rydvik et al did in the mid 90s show that the inflammatogenic properties of nucleus pulposus per se can induce nerve involvement without pressure to the nerve (102, 118). This observation has since been confirmed in many studies (34, 103). Biochemical effects on spinal nerves may well be the foremost reason why MRI cannot be

considered a sensitive diagnostic method to detect nerve involvement in the spine.

Future studies will have to evaluate the association between spinal pain and dysfunction and MRI findings like the HIZ, Modic changes and other findings of disc damage that may induce nerve involvement or local pain (3, 108). Also functional (kinetic) MRI recordings, for example while standing, sitting and moving the spine should be further studied. Electro-physiological methods like quantitative sensory testing and cerebrospinal fluid and other laboratory findings that may indicate nerve involvement may also be studied to help today's `MRI – invisible spine patient (7, 25, 128, 159).

Future perspectives

We will further analyse our material to assess the association between clinical and radiological findings in the cervical spine and also the inter-examiner reliability in the MRI assessment.

Future studies may, as mentioned in the discussion, use our findings and further assess the association between clinical and other diagnostic methods of nerve involvement such as electro-physiological methods, laboratory methods, PET scans and MRI findings of different kind as well as functional MRI recordings (3, 86, 108, 149, 159).

A possible association between nerve involvement originating in the spine and pain and/or organ dysfunction is another interesting area for future studies where our findings may be used. Fibromyalgia, visceral dysfunctions and tendalgia including for example patellofemoral pain are symptoms with unknown origin where the hypothesis of nerve involvement originating in the spine has not been duly considered (50).

If our present conclusions on nerve involvement and further hypothesis stand future scientific testing then clinics that care for musculoskeletal disorders, the spine care community and the pharmaceutical industry may have to adopt a new view of what is needed to meet and treat these patients effectively.

Conclusions and clinical implications

1. Many common clinical tests used in our assessment of cervical and lumbar spine discomfort showed less than acceptable inter-examiner reliability. However, a sensibility test with spurs showed good inter-examiner reliability in the assessment of both cervical and lumbar spine discomfort.
2. Patient history had no impact on inter-examiner reliability of clinical tests in the neck/shoulder region but increased prevalence of positive findings.
3. The simplified pain drawing showed good inter-examiner reliability for first impression assessment of nerve involvement, even though two thirds of the patients added symptoms during history session. The process to learn to use the pain drawing was easy.
4. The KWC proved to be a reliable pathoanatomic classification system not dependent of radiological findings.
5. MRI visible nerve involvement significantly underestimated the presence of nerve involvement detected in the physical exam and in the pain drawing on patients referred to lumbar MRI.
6. Signs and symptoms of nerve involvement originating in the spine was very common among our open care patients, both those with neck/shoulder (cervical) and those with lumbar dysfunctions.

1. Common clinical tests used in the assessment of spine dysfunctions should be interpreted with caution. The bimanual sensibility test may be recommended for detection of nerve involvement and further studies.
2. History should precede physical examination in order to guide the clinical testing procedure.
3. The simplified pain drawing may be recommended to assess nerve involvement in an area of discomfort. Patients should be asked to describe the whole truth as this may add clues to the origin of their discomfort.
4. KWC may be recommended for assessment of low back pain.
5. Other factors than visible nerve involvement – on the MRI – may be responsible for findings of nerve involvement in the physical exam and the pain drawing.
6. Nerve involvement originating in the spine may be a greatly underestimated cause of pain and/or organ dysfunction, both in the cervical and lumbar region. This may explain part of today's poor treatment outcome of spinal pain and dysfunction and should encourage further studies on diagnostic methods and treatment of nerve involvement.

   The simplified pain drawing and a structured physical exam including the bimanual sensibility test with spurs is recommended to detect if patients are in need of treatment aimed at nerve involvement originating in the spine.

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Sammanfattning på svenska (Summary in Swedish)

Nervpåverkan med ursprung i ryggraden kan orsaka smärta och/eller organdysfunktion. Reliabel och valid bedömning av nervpåverkan är en primär diagnostisk uppgift eftersom nervpåverkan kan kräva annat än symptomatisk behandling.

Syftet med denna avhandling var att analysera reliabilitet i och samband mellan vissa diagnostiska metoder och klassificeringar som används vid bedömning av patienter med spinal smärta. I synnerhet reliabilitet i och samband mellan metoder som används för att upptäcka nervpåverkan med ursprung i ryggraden.

Material. Artikel I och II baseras på studie A där 100 konsekutiva primärvårdspatienter med nack- och/eller axelbesvär bedömdes av 2 oberoende undersökare med hjälp av en förenklad smärtritning, anamnes och fysiskaliskt status med 66 kliniska tester inriktade på neurologi. Artikel III baseras på studie B där 50 konsekutiva patienter med ländryggsmärta i öppenvården, bedömdes av 2 oberoende undersökare med hjälp av anamnes och fysiskaliskt status med 30 kliniska tester. Artikel IV baseras på studie C där 61 konsekutiva patienter remitterade till magnetisk resonans tomografi (MRT) av ländrygg bedömdes utifrån förenklad smärtritning, anamnes och fysiskaliskt status inriktad på neurologi för att upptäcka eventuell nervpåverkan ifrån ryggraden.

Resultat. I studie A var inter-bedömmar reliabiliteten tveksam för många tester. Endast ett tvåhändigt känseltest med sporrar nådde $\kappa > 0{,}6$ talande för god reliabilitet och därtill ingen bias. Med känd anamnes, ökade förekomsten av positiva fynd men inte reliabiliteten. Fyra av fem patienter hade, i besvärsområdet, två eller fler kliniska test talande för nervpåverkan med ursprung i ryggraden. Inter-bedömmar reliabilitet grundad på första intrycket av smärtritningen nådde 88% övergripande överensstämmelse och en sensitivitet på 90% till fysikaliska test påvisande nervpåverkan. Två tredjedelar av patienterna adderade symptom på nervpåverkan på smärtritningen under anamnesupptagningen.

I studie B konstaterades utmärkt reliabilitet ($\kappa > 0.8$) för Kirkaldy-Willis Klassificering av ländryggsmärta. Radiologiska fynd påverkade ej reultatet. God inter-bedömmar reliabilitet påvisades för rakt benlyft, rörelseuttag och känseltest med sporrar.

I studie C fann vi att på MRT synlig nervpåverkan statistiskt signifikant underskattade nervpåverkan som upptäcktes i fysiskaliskt status och på smärtritningen.

Slutsatser. Nervpåverkan kan påvisas reliabelt, enkelt och snabbt med ett tvåhändigt känseltest med sporrar och en smärtritning. På MRT synlig nervpåverkan underskattar förekomst av nervpåverkan som upptäckts i fysiskaliskt status och smärtritning. Nervpåverkan med ursprung både i hals- och ländyggen kan vara en mycket underskattad orsak till smärta och/eller organdysfunction. Detta kan förklara en del av dagens tveksamma behandlingsresultat av spinal smärta och bör uppmuntra till vidare studier av diagnostiska metoder och behandling av nervpåverkan med ursprung i ryggraden.

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