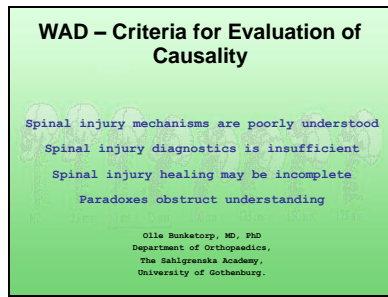


Bild 1



Whiplash has caused frustrating problems since decades – and some people even deny the existence of WAD.

In fact, WAD is difficult to understand, because spinal

- injury mechanisms are poorly understood,
- diagnostic procedures are insufficient,
- injury healing may be incomplete.

This pertains especially to

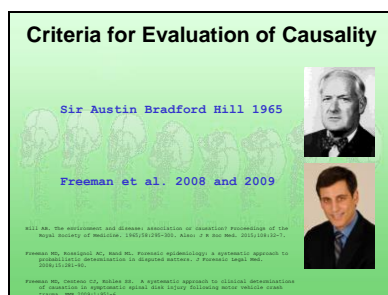
- estimation of crash severity,
- injury tolerance,
- pain physiology.

Moreover, some circumstances are paradoxical.

This is why many WAD patients are met with distrust by the health care system and insurance companies.

This presentation aims to describe some of these inconveniences.

Bild 2



There are welldefined criteria, which should be used to assess whether there is a causal link between a harmful event and a consequent disorder.

They were first presented by Sir Austin Bradford Hill, already in 1965.

Freeman et al. made a thorough review in 2008 and 2009. The second paper gave specific reference to symptomatic spinal disk injury following motor vehicle trauma.

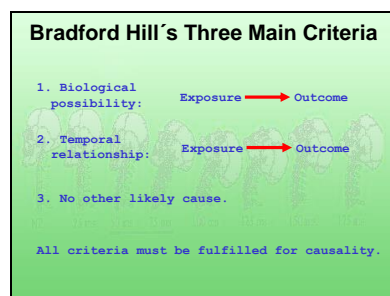
References:

Hill AB. The environment and disease: association or causation? Proceedings of the Royal Society of Medicine. 1965;58:295-300. See also: J R Soc Med. 2015;108:32-7.

Freeman MD, Rossignol AC, Hand ML. Forensic epidemiology: a systematic approach to probabilistic determination in disputed matters. J Forensic Legal Med. 2008;15:281-90.

Freeman MD, Centeno CJ, Kohles SS. A systematic approach to clinical determinations of causation in symptomatic spinal disk injury following motor vehicle crash trauma. PMR 2009;1:951-6.

Bild 3



The originally criteria can be reduced to three main parts:

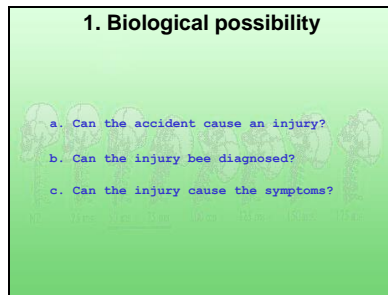
First: There must be a plausible or possible relationship between the exposure and the effect or outcome.

Second: There must be a temporal relationship between exposure and outcome.

Third: There must not be a more likely other explanations for the outcome.

All three must be fulfilled for causality.

Bild 4



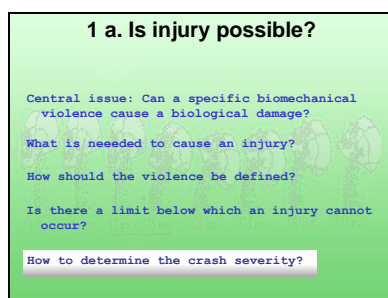
The first criterion can be divided in three parts

Can the accident cause an injury?

If so, can the injury be identified or diagnosed?

And finally, can the injury cause the symptoms?

Bild 5



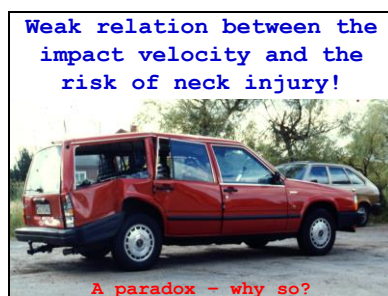
The central issue is whether a specific car crash may cause some biological damage.

What is needed to cause an injury?

Is there a limit below which an injury cannot occur?

Especially, how to determine the crash severity.

Bild 6



The crash severity is often referred to.

In general, it is reasonable to assume that the greater the crash, the greater the injury risk.

However, this is not always true.

In fact, there is only a weak relation between the impact velocity and the neck injury risk in ordinary rear-end impacts.

This is a paradox.

Why is it so?

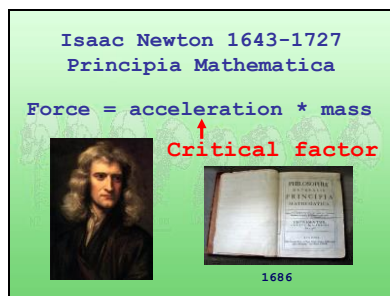
To understand this, we must recognize some biomechanical facts.

Bild 7



Injuries are caused by forces that cause deformations.

Bild 8



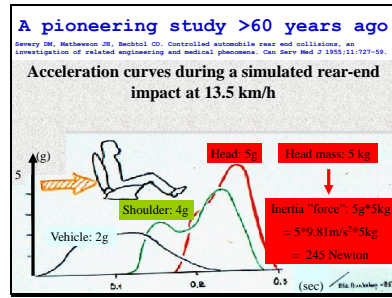
We must also remember what Isaac Newton taught us.

The force is equal to acceleration multiplied by mass.

Note - this equation does not include velocity.

Acceleration is the critical factor.

Bild 9



These are accelerations curves during a low speed rear-end impact in a pioneering study, presented over sixty years ago.

The black curve describes the acceleration of the vehicle. Its maximum is two g.

The green curve is the acceleration of the shoulder. It has two maxima, the greatest peak is four g.

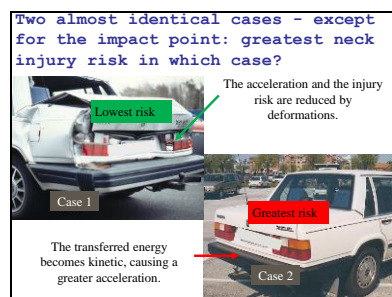
The red curve is the acceleration of the head. The head's peak acceleration is five g.

This means - if the head weighs five kilogram - its inertia force is two-hundred and forty-five Newton.

This is like having twenty kilogram mounted on the head during a short movement.

Don't try that, because it may hurt your neck.

Bild 10



Now, what could explain the velocity paradox?

These two cars were impacted from behind. All factors were identical - except for the impact point.

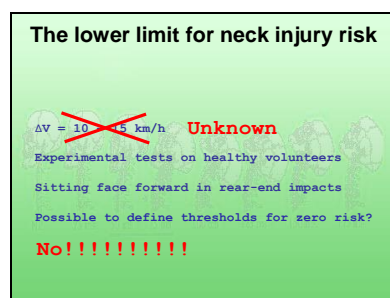
Which case provides the greatest risk of neck injury?

The answer is case 2, because most of the transferred energy becomes kinetic, causing a greater acceleration.

In case 1, the acceleration and the injury risk are reduced by deformations.

Thus, one cannot estimate the crash severity by just looking at the damage of the car.

Bild 11



The lower limit for neck injury risk in rear-end impacts is alleged to be delta V - meaning a velocity change - between 10 and 15 km per hour.

However, this limit is based on tests on healthy volunteers - simulating a car occupant sitting face forward in a rear-end impact.

The question is – is it possible to define a threshold or a lower limit for zero risk?

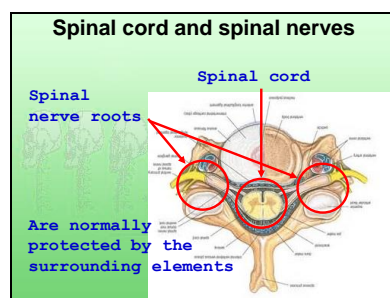
The answer is no – because you have to examine an infinite number of cases.

And, any such a limit is falsified by finding just one injured case below this limit.

Remember, traffic injuries do not affect healthy volunteers only – but all kind of people.

To understand this, one has to consider some important facts related to anatomy, pathophysiology, and how people are injured in real accidents.

Bild 12

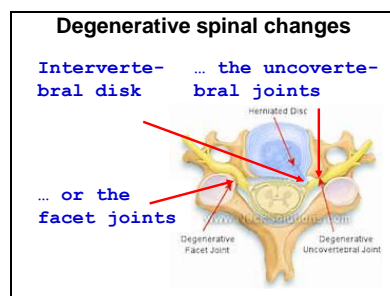


This is a cross section of the spine and the adjacent nerve structures.

The spinal cord and the spinal nerves are located inside the spinal canal.

Normally, they are protected by the canal itself – in most cases.

Bild 13



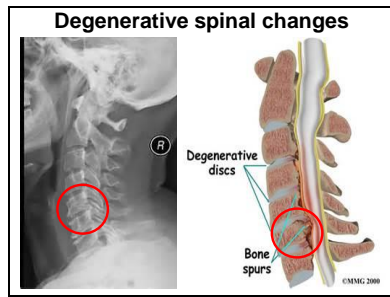
However, in many cases the spinal canal is not normal. Instead it is encroached by degenerative changes.

Degenerative spinal changes affect

- the intervertebral disk,
- the unco-vertebral joints - the small joints between the vertebral bodies,
- and the facet joints.

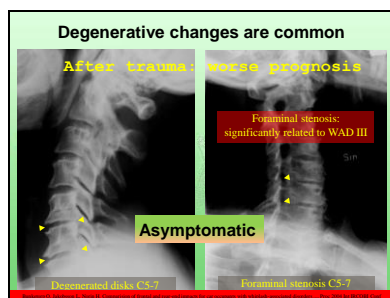
Degenerative changes can damage the spinal cord and the nerve roots – especially during acceleration.

Bild 14



Degenerative spinal changes are often seen as bone spurs at the vertebral edges on X-rays.

Bild 15



Degenerative changes are common. In fact, most of us have degenerative spinal changes.

The picture to the left shows two degenerated disks between the fifth and the seventh vertebrae.

And to the right stenosis of two nerve root canals in the lower part of the neck

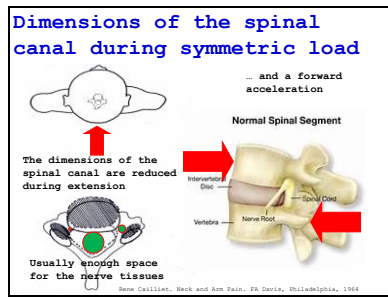
Such changes are usually asymptomatic.

Until the neck is exposed to a trauma.

In one of our studies, foraminal stenosis was significantly related to WAD grade III. This means a neurological injury and a worse prognosis.



Bild 16

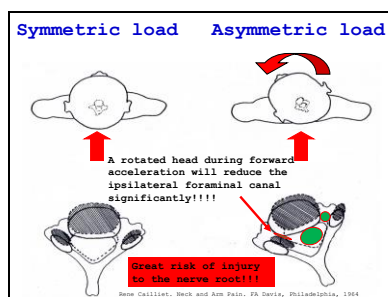


The dimensions of the spinal canal will influence the injury risk of nerve structures during movements or acceleration.

The sagittal diameter is reduced during extension and during a forward acceleration.

But, the space for the cord and the nerve roots is usually enough during a symmetric load.

Bild 17



Asymmetry – for instance a rotated head - means a greater risk of injury to nerve tissue.

Especially, if there are degenerative changes.

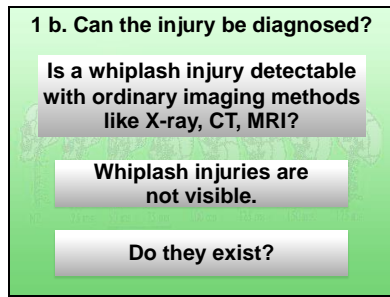
The same is true in oblique impacts.

Bild 18



So - don't turn the head in a collision!

Bild 19



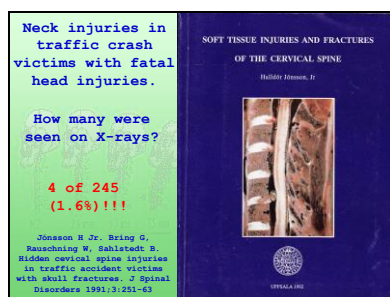
The next problem is the difficulty to diagnose injuries causing WAD.

This means, can whiplash injuries be detected with X-ray, CT or MRI?

No – as by definition, whiplash injuries are usually not visible.

But – do they exist?

Bild 20



This was investigated by Halldór Jónsson and co-workers – one of them was Gunilla Bring.

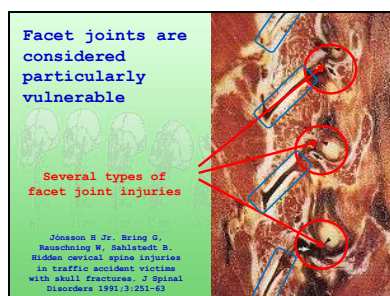
They studied neck injuries in traffic accident victims with fatal head injuries.

How many were seen on X-rays?

Only four out of two-hundred and forty-five injuries – or 1.6%.

Of course - this is not a proof that all whiplash trauma will cause such injuries – it just shows how difficult it is to detect minor spinal injuries.

Bild 21

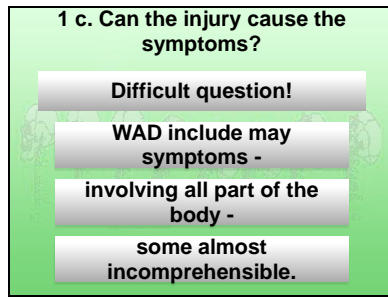


The facet joints are very vulnerable.

These are the small joints on each side between the vertebrae.

There were several types of facet joint injuries.

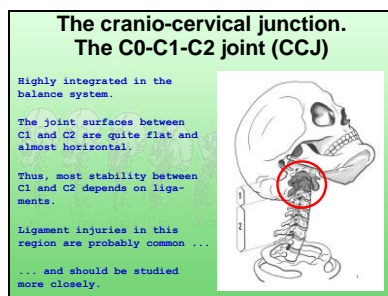
Bild 22



The next question is – can the injury cause the symptoms?

This is a difficult question - because WAD can include many symptoms - involving all parts of the body – and some are almost incomprehensible.

Bild 23



This is easily understood if you look at the uppermost part of the neck, the Cranio-Cervical Junction or CCJ. This a sophisticated construction

- highly integrated in the balance systems.

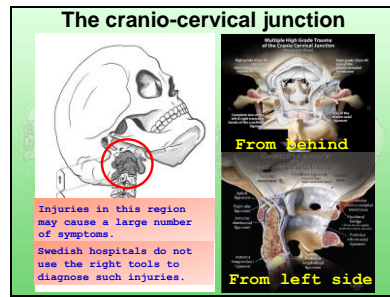
The surfaces between C1 and C2 are quite flat and almost horizontal, so

- most of the stability between C1 and C2 depends on ligaments,.

Ligament injuries in this region are probably common,

- and should be studied more closely.

Bild 24



There are several other important structures in the cranio-cervical region.

Up to the right is a schematic view, from behind, showing some of them.

Below it is a view from the left side.

Obviously, this is a very complicated region – and notice – the brain, the spinal cord, the cranial nerves, and the vessels are not shown.

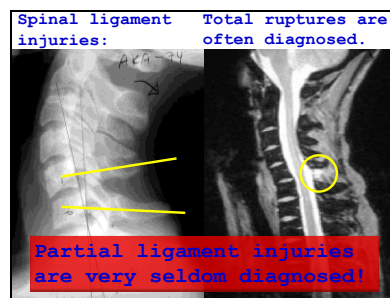
It is easy to understand that injuries in this region might cause a great number of symptoms.

So far- we do not know how often such injuries occur.

Because we lack reliable medical studies.

In fact, Swedish hospitals usually don't even use the right tools to diagnose such injuries.

Bild 25



Obvious ligaments injuries in other parts of the neck can be diagnosed quite easily.

On this radiograph, there is an obvious spread of the spinous processes of C5 and C6, which indicates a significant ligament injury.

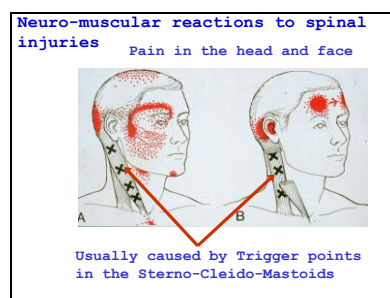
The ligament injury was verified on MRI and could be treated successfully.

However, partial ligament injuries are seldom diagnosed in WAD-patients – not even in the middle or lower neck.

They are often compensated for by muscular tension.

Long standing muscular tension may cause disturbances of the neuro-muscular system.

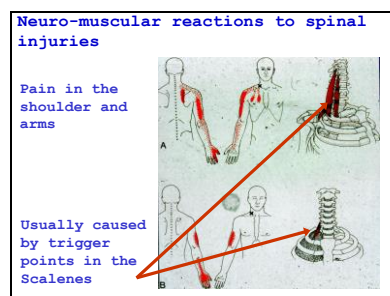
Bild 26



If neck muscles are activated for a long time, muscular trigger points can develop.

Trigger points in the Sternocleidomastoid refer pain to the head and face.

Bild 27



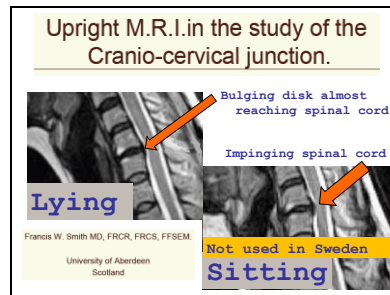
Trigger points in the Scalenes refer pain to the shoulder and arm.

In fact, such arm symptoms often are misjudged as caused by pressure on a nerve root.

Trigger points are quite common, and they can arise in all muscles.

Trigger points often cause mysterious symptoms, which are seldom diagnosed correctly.

Bild 28



This picture was presented by Francis Smith some years ago.

It shows the effect of gravity on disk bulging.

Almost all MRI investigations are made with the patient lying.

There is a bulging disk, almost touching the spinal cord when lying.

However, in sitting position, there is a clear impingement on the cord.

Upright MRI is used in some countries – but not in Sweden.

Some people even claim that upright MRI is not scientifically evaluated.

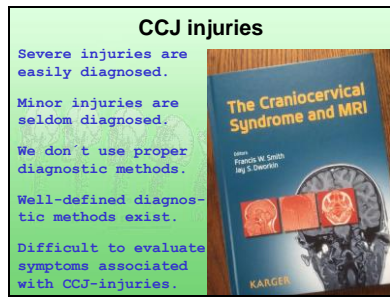
This is a lie and serious limitation of the diagnostic potential for a large number of people.

In fact, there are over 9000 scientific references on upright MRI in PubMed.

Besides, there are also MR-cameras and X-ray equipment that take pictures during movement.

This is remarkable that this is not used in Sweden, because people spend most of their time moving in an upright position.

Bild 29



Severe injuries to the craniocervical junction are easily diagnosed, because they are often fatal.

Minor injuries, however, are seldom diagnosed.

Because, we don't use proper diagnostic methods.

In spite of the fact that they have been thoroughly described since many years.

It seems like there is no interest in this part of the body.

This might depend on the difficulty to evaluate the many symptoms associated with CCJ-injuries.

Bild 30



The second criterion has to do with time.

It can be divided in two parts.

First, the injury symptoms should not start too late.

But – what too late is depends on several factors, like

- severity of injury
- type of injury
- localization of the injury
- etcetera

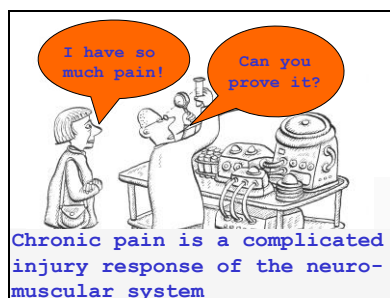
The second part pertains to variation of symptoms by time – i.e. continuity.

There should not be long periods completely free of symptoms.

However, what is a “long period”?

And – don’t confuse injuries with pain!!!!

Bild 31



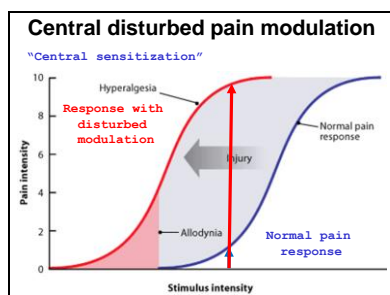
The most common WAD symptom is pain.

Chronic pain is a complicated injury response of the neuro-muscular system.

It may be triggered by incomplete healing of certain tissues, like ligaments, joint capsules, and cartilage.

It also depends on other factors, which are not yet completely understood.

Bild 32



Central disturbed pain modulation or central sensitization is a phenomenon that increases pain.

Without any morphological changes of the injury.

This depends on neurophysiological reactions to the injury.

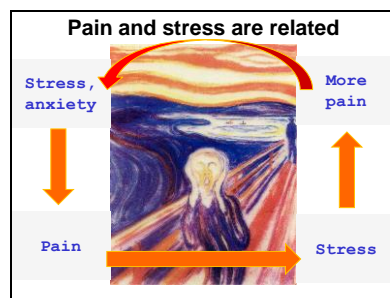
In such cases, the perceived pain intensity is increased.

Or, a pain stimulus that causes a normal pain response in a healthy person



- will cause hyperalgesia in a sensitized person.

Bild 33



Pain and stress are related.

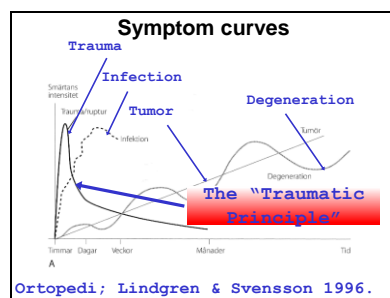
Stress and anxiety increases the risk of pain.

And pain leads to stress.

Which creates more pain

In a vicious circle.

Bild 34



These curves show symptom developments for different diagnoses.

- Traumatic injuries
- Infections
- Tumors
- Degeneration

The trauma curve has been referred to as the "Traumatic Principle" by medical advisors of Swedish insurance companies.

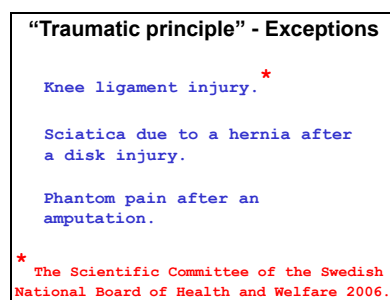
Actually, they have claimed that deviations from the trauma curve proves that the symptoms are not caused by a trauma.

This is not true.

Because this curve just shows the mean progress of an injured population.

There is always a distribution around the mean in biological processes.

Bild 35



But, there are exceptions from the Traumatic Principle.

A knee ligament injury is a typical example.

There are also other exceptions like

- sciatica due to a disk hernia, evolving some months after a partial rupture of the disk, and
- phantom pain after an amputation.

Bild 36



Knee ligament injuries are quite common.

A cruciate ligament injury may cause degenerative changes of the joint cartilage.

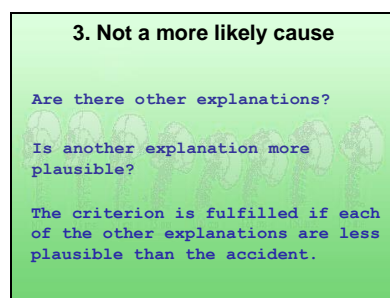
And this gives increasing pain and stiffness after a couple of years.

Nothing contradicts that this can also occur after ligament injuries in spinal joints

There are 16 facet joints and similar joints in the cervical spine.

And, each of them can develop instability due to a ligament injury.

Bild 37



The third criterion is that there must not be a more likely cause for the outcome.

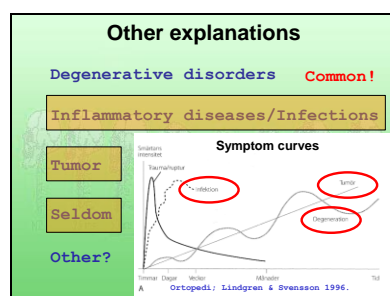
To determine this, one must consider several items.

First, are there other explanations?

Second, is another explanation more plausible?

The criterion is fulfilled if each of the other explanations are less plausible than the accident.

Bild 38



What are the other explanations?

Look at the symptom curves.

A common explanation is degenerative disorders.

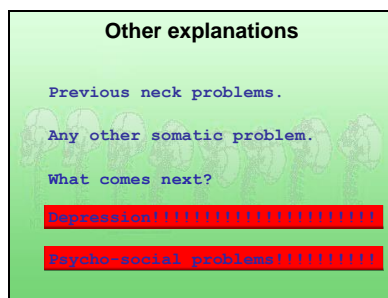
There are also infections and inflammatory disorders, like rheumatoid arthritis.

And tumors.

These are all possible.

Are there other explanations?

Bild 39



Previous neck problems are often regarded as an alternative cause.

- or any other somatic problem – whatever it may be.

What comes next?

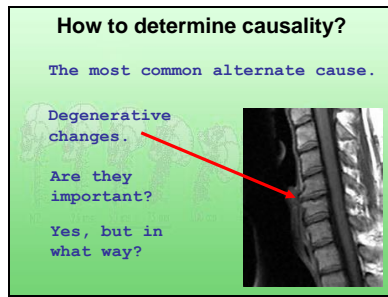
I don't know.

But, I know what often is regarded as competitive causes.

Depression.

Psycho-social problems of any kind.

Bild 40



How should causality be determined?

Let us take the most common alternate cause – degenerative changes.

Are they important?

Yes – but in what way?

Bild 41



In fact, degenerative changes increase the risk of injury!!

It's just like old persons. They can't stand stress as a youth.

Besides, degenerative changes increase the risk of nervous structures.

Bild 42

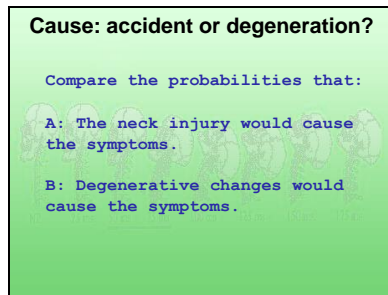


Normally, degenerative spinal changes are asymptomatic.

Most often they don't cause pain.

They cause reduced mobility and stiffness.

Bild 43



How is causation settled?

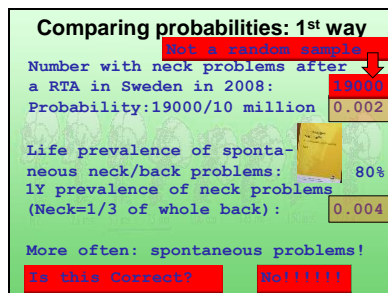
The most straightforward way is to compare probabilities.

On one side, the probability that the neck injury would cause the symptoms,

And on the other, the probability that there is another explanation.

Let us take degenerative changes as it is most common.

Bild 44



One way to estimate probability is with prevalences – i.e. occurrences by time.

On one side we have people with neck problems after a road traffic accident.

They were 19 000 in Sweden in 2008. With 10 million people, this gives a probability equal to about 0.002 or 0.2% that a randomly selected person in Sweden will have neck pain after a traffic accident.

On the other side we have people with spontaneous neck pain during this year.

With data from the report 2000 - the one year prevalence of spontaneous neck pain is 0.004, or 0.4%

This number is greater than that for neck pain due to injury.

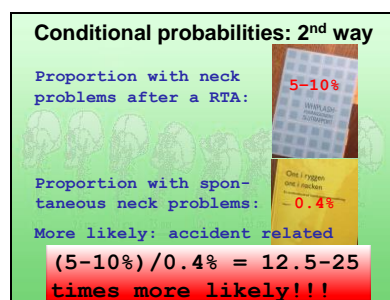
So, spontaneous neck pain it is more common than neck pain after a traffic accident.

Accordingly, some people conclude that an accident is a less likely cause.

Is this correct?

No – because people with neck pain one year after an accident are not a random sample.

Bild 45



In fact we have a condition for our selection – we must select from those who had a neck injury during the last year.

How often do they have neck pain after one year?

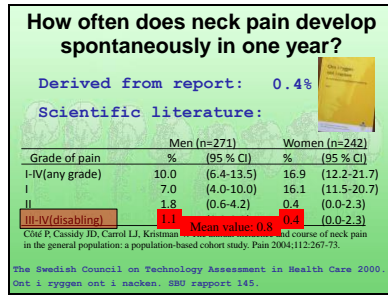
Five to ten percent according to the Swedish Whiplash Commission.

The percentage with spontaneous neck pain was 0,4%.

If we compare these percentages, the accident is a more likely cause.

In fact, it is at least 12 times more likely.

Bild 46



The rate of spontaneous neck pain 0.4% was derived from the Swedish report.

How correct is this figure according to the literature?

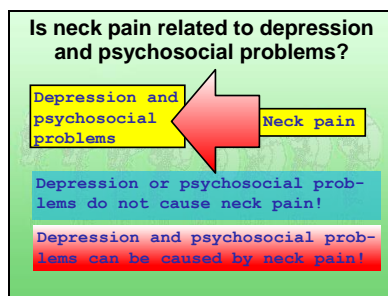
There is only one scientific study that presents incident figures on spontaneous neck pain.

On the other hand, it's well-done.

The one-year incidence of disabling neck pain was 1.1% for men and 0.4% for women.

The mean value was 0.8%

Bild 47



Neck pain is said to be related to depression and psychosocial problems?

Is this true?

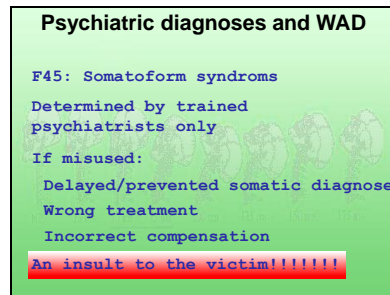
Yes, but the relation is causal only in one direction.

Depression or psychosocial problems do not cause neck pain!

However, depression and psychosocial problems can be caused by neck pain.



Bild 48



Some WAD problems are difficult to understand.

Some symptoms may resemble Somatoform syndromes.

This means a psychiatric disorder with ICD-code F45.

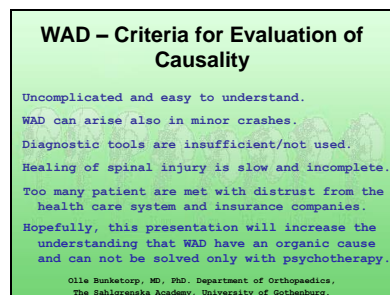
This psychiatric diagnosis should be determined by an experienced psychiatrist only.

A misuse of this diagnose may lead to

- delayed or prevented somatic diagnose,
- wrong treatment,
- incorrect compensation.

It's also an insult to the victim!

Bild 49



To summarize, the criteria for evaluation of causality in WAD cases are uncomplicated and easy to understand - but

You must realize that WAD can arise also in minor crashes.

The diagnostic tools are insufficient or not used.

Healing of spinal injury is slow and incomplete.

Too many WAD patients are met with distrust by the health care system and insurance companies.

Hopefully, this presentation can eliminate some of these inconveniences.

Bild 50



Even if there is an ocean of  
knowledge, not yet understood.

We have to explore it – and enjoy the  
voyage!

Thank you!