

# Structured image diagnosis of vertebral body degeneration and intervertebral disc damage – Binary image criteria and comparison for systematic image analysis for occupational diseases 2108 and 2110

## Part 2: “Comparison images”

## Strukturierte Bild-Befundung von Wirbelkörperdegeneration und Bandscheibenschäden – Binäre Bildkriterien und Vergleichsbilder für die systematische Bildanalyse bei den Berufskrankheiten 2108 und 2110

### Teil 2: „Vergleichsbilder“

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#### ABSTRACT

**Background** Job-related limitations of earning capacity are eligible for recognition under social legislation and may be subject to compensation (see Part 1).

**Method** For the recognition of an occupational disease (BK), diagnostic imaging is required as part of the legal determination procedure for occupational diseases 2108/2110 (“occupational disc disease”). The focus is on image criteria on X-ray images and MRI examinations. In a consensus paper under the guidance of the German Social Accident Insurance Institutions from 2005, the characteristic patterns are defined and explained extensively and summarized in typical occupation-related constellations. This article presents representative image examples as a reference system for expert reporting as far as the typical patterns from the consensus paper are concerned.

**Conclusion** In Part 2, comparison images with the typical findings of the vertebral bodies and intervertebral discs according to occupational diseases are systematically presented, explained, and offered as a reference system for expert assessment. The image criteria can be used as “evidence by eye” (Heuck) in the recognition procedure.

#### Key Points

- Occupational diseases are defined by the legislator in the “List of Occupational Diseases”.
- For occupational intervertebral disc diseases (OD nos. 2108/2110), constellations of findings are defined.
- Within the scope of diagnostic imaging, a large number of image criteria are used.
- Part 1 explains the basics and the legal background.
- Part 2 provides the image criteria on the basis of “comparison images” as a reference catalog.

## Citation Format

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## ZUSAMMENFASSUNG

**Hintergrund** Berufsbedingte Einschränkungen der Erwerbsfähigkeit sind gemäß der Sozialgesetzgebung anerkanntsfähig und ggf. schadenersatzpflichtig (s. Teil 1).

**Methode** Für die Anerkennung einer Berufskrankheit (BK) ist im Rahmen des juristischen Feststellungsverfahrens bei den Berufskrankheiten 2108/2110 („berufsbedingte Bandscheibenerkrankungen“) vor allem auch die bildgebende Diagnostik erforderlich. Im Mittelpunkt stehen Bildkriterien bei Röntgenbildern und MR-Untersuchungen. In einem Konsenspapier der Deutschen Gesetzlichen Unfallversicherungsträger des Jahres 2005 werden die charakteristischen Schadensbilder definiert

und umfangreich erläutert. Der vorliegende Artikel legt repräsentative Bildbeispiele als Referenzsystem für die gutachterliche Befundung vor.

**Schlussfolgerung** Im Teil 2 werden Vergleichsbilder mit den typischen Kriterien der einzelnen Schadensformen an Wirbelkörpern und Bandscheiben systematisch vorgestellt, erläutert und als Referenzsystem für die gutachterliche Beurteilung angeboten. Die Bildkriterien können als „Beweismittel nach Augenschein“ (Heuck) im Anerkennungsverfahren eingesetzt werden.

## Kernaussagen

- Berufskrankheiten werden seitens des Gesetzgebers in der „Liste der Berufskrankheiten“ festgelegt.
- Für berufsbedingte Bandscheibenerkrankungen (BK 2108/2110) sind Befundkonstellationen definiert.
- Im Rahmen der bildgebenden Diagnostik kommen eine Vielzahl von Bildkriterien zum Einsatz.
- Teil 1 erläutert hierfür die Grundlagen.
- Teil 2 stellt die Bildkriterien anhand von „Vergleichsbildern“ als Referenzkatalog zur Verfügung.

## I. Introduction

As described in part 1 [1], job-related limitations of earning capacity are eligible for recognition under social legislation and may be subject to compensation (see list of occupational diseases [2]). The basis for evaluating causality giving rise to liability includes diagnostic imaging as “evidence by eye” [3].

## II. Goal

Part 1 presented diagnostic definitions and clinical classifications. Part II provides corresponding image examples as “comparison images”.

The goal of the reference material provided in part 2 is to support image evaluation as part of the medical expert opinion for occupational disease nos. 2108 and 2110 with comparative image analysis and to illustrate the image criteria and classifications of findings specified in the consensus paper in a reproducible manner.

Clinical and procedural information for the interdisciplinary expert opinion process (symptoms, images) is provided in part I and its use is recommended for quality assurance.

## III. “Comparison images”

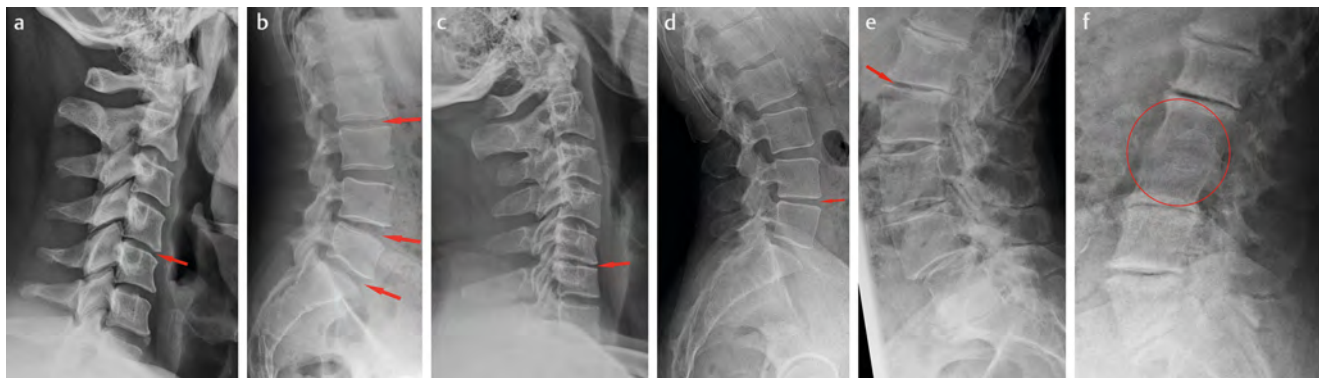
The diagnostic criteria listed in the consensus paper [4] are to be analyzed in the expert opinion for occupational disease nos. 2108 and 2110 both for the cervical spine and the lumbar spine. The report should include osseous (projection radiography) and intervertebral disc findings (MRI).

Using comparison images (► Fig. 1–9), the following list of “diagnostic criteria” based on definitions and image analysis [4] allows:

- a) Confirmation/exclusion (“binary image criteria”: see part I),
- b) Semiquantitative determination (grading) of the degree of severity,
- c) Synoptic assessment of a “load-conforming damage pattern”, and thus
- d) Morphological differentiation from non-occupational diseases (e. g., “competing factors”/“E-constellations”: [4]).



► **Fig. 1** **a** Normal cervical spine finding, normal distances between the vertebrae of the cervical spine are as follows:  $C2/3 < C3/4 < C4/5 < C5/6 \geq C6/7$ . **b** Normal lumbar spine finding, normal distances between the vertebrae of the lumbar spine are as follows:  $L1/2 < L2/3 < L3/4 < L4/5 \geq L5/S1$ .



► **Fig. 2** **a** Chondrosis grade I – cervical spine: Height reduced at the midline level to half height, 40 % in this example. **b** Chondrosis grade I – lumbar spine: Height reduced at the midline level  $\geq 1/5$  to  $1/3$ . **c** Chondrosis grade II – cervical spine: Height reduced at the midline level  $> 1/2$ , 55 % in this example. **d** Chondrosis grade II – lumbar spine: Height reduced at the midline level  $> 1/3$ – $1/2$ , 45 % in this example. **e** Chondrosis grade III – lumbar spine: Height reduced at the midline level  $> 1/2$ , 65 % in this example. In this example, the intervertebral disc space L1/2 can only be compared with segments L2/3 and 3/4. **f** Chondrosis grade IV – lumbar spine, ankylosing chondrosis. Caution: To be differentiated from traumatic and dysontogenetic block vertebrae!

Under consideration of all individual findings, their classification as age-typical/not age-typical, and work-related analyses, a constellation of findings (groups A, B, C, etc.) can be developed.

#### User information regarding comparison images:

- Use of the “comparison images” is preceded by the definition of the diagnostic criteria (according to Dihlmann for radiography and Pfirman or Vahlensieck for MRI) and grading according to the consensus paper [4].
- ► **Fig. 1a, b** show “unremarkable findings” (i. e., normal configuration and structure as the reference image for systematic image analysis). Comparison images for chondrosis are shown in ► **Fig. 2a–f**, sclerosis in ► **Fig. 3a–d**, spondylosis in ► **Fig. 4a–c**, spondyloarthritis in ► **Fig. 5a–b**, intervertebral disc degeneration in ► **Fig. 6a, b**, and intervertebral disc extrusion in ► **Fig. 7a, b**.
- The arrows identify the pathological findings in each image.

### A. “Normal findings”

Normal structure and contour of the spine; physiological, cranio-caudal increase and decrease in the height of the intervertebral spaces.

### B. “Degenerative diagnostic criteria”

**Chondrosis** (syn. *chondrosis intervertebralis*), see 5.7 Consensus recommendations)

Definition: Disc damage with a decrease in the intervertebral spaces on lateral images without changes in the bony end plates. ► **Table 1** shows the grading, and ► **Fig. 2a–f** show image examples.

#### Processing information:

- The grade of chondrosis is determined primarily by comparison with the comparison images. An exact measurement of the intervertebral disc height [5–7] can support the conclusion in cases of doubt. Even in the case of a clear finding (grade III chondrosis), a measurement can be helpful with respect to a comparative decrease in the height of additional intervertebral discs.

- In the case of clear constellations of findings that meet the requirement for recognition (three affected intervertebral discs with chondrosis  $>$  grade II and/or slipped disc and/or secondary spondylosis), this measurement can be omitted. Measurement is also not necessary if there is clearly no decrease in the height of an intervertebral disc.
- The measurement of the intervertebral disc heights of the lumbar spine as described by Hurxthal [6, 7] cannot be used in the case of narrowing of the intervertebral discs in all segments due to false-negative results. A comparative description under consideration of “normal findings” is usually sufficient in such cases (► **Fig. 1a, b**).
- Measurement of the intervertebral disc heights of the cervical spine is not established since current data does not allow comparable classification as in the lumbar spine.
- Incorrect measurement results can also occur when the segments are not measured using an orthogonal line so that the measurement points do not take the exact mid-line of the oval surfaces of the end plates into account (“midline measurement”).

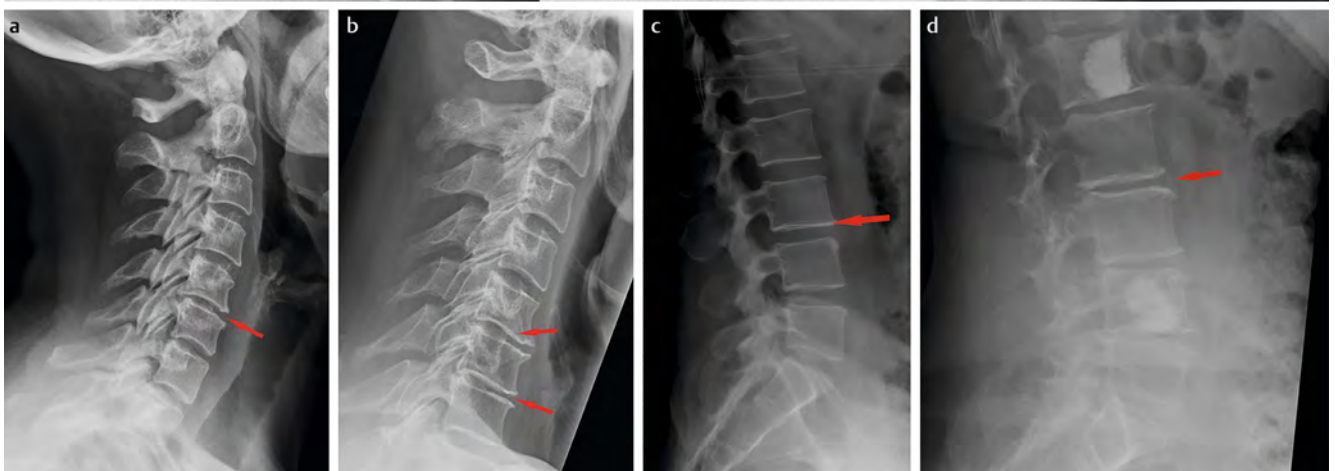
**A “load-conforming damage pattern” is defined as intervertebral disc damage with at least grade II chondrosis and/or a slipped disc, and with secondary spondylosis or a multisegmental damage pattern, with more than 2 segments being affected. MRI is usually necessary to show this.**

- **Fig. 2a–f** show the grades of sclerosis.

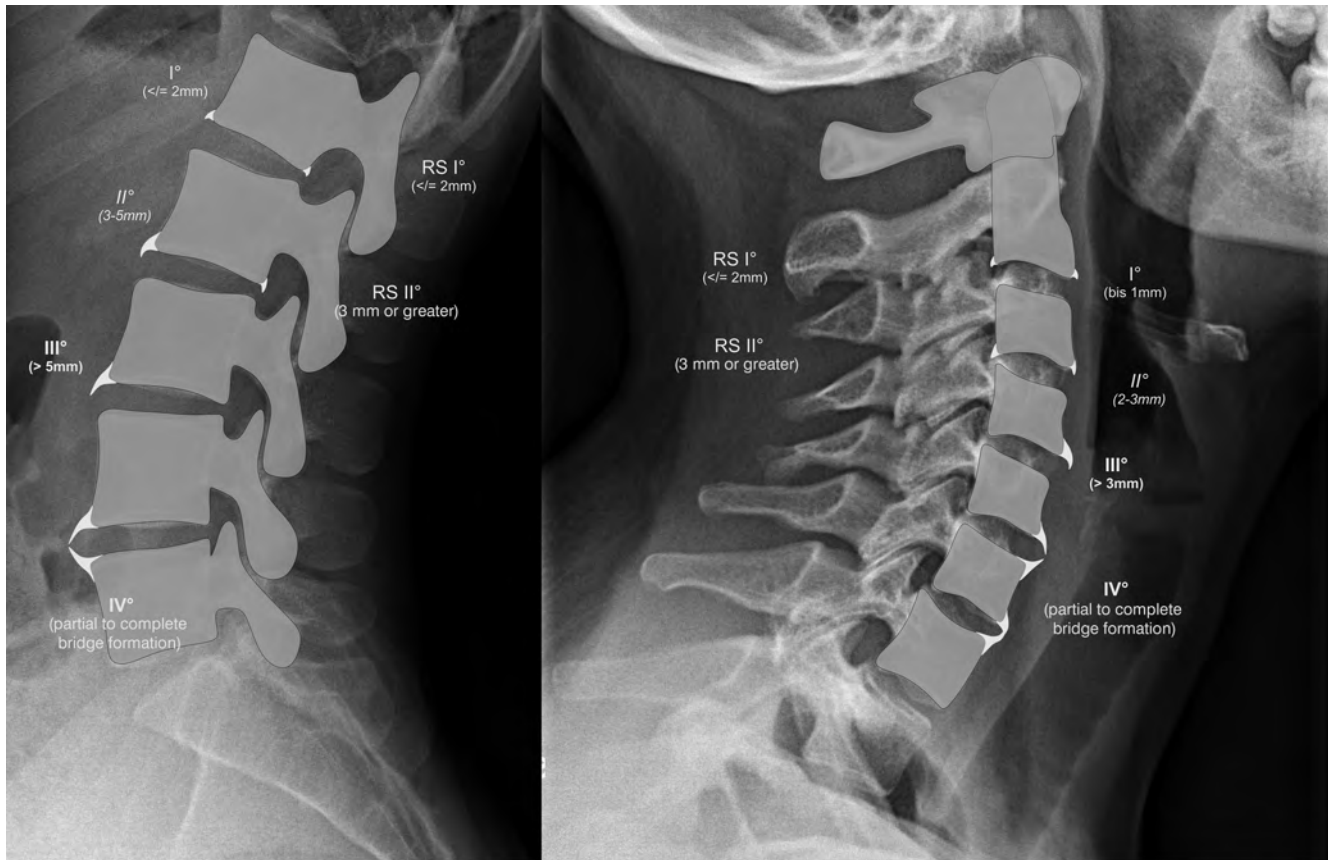
#### Sclerosis

Definition: Significant sclerosis of the end plates that is independent of a reduction of the height of the intervertebral disc.

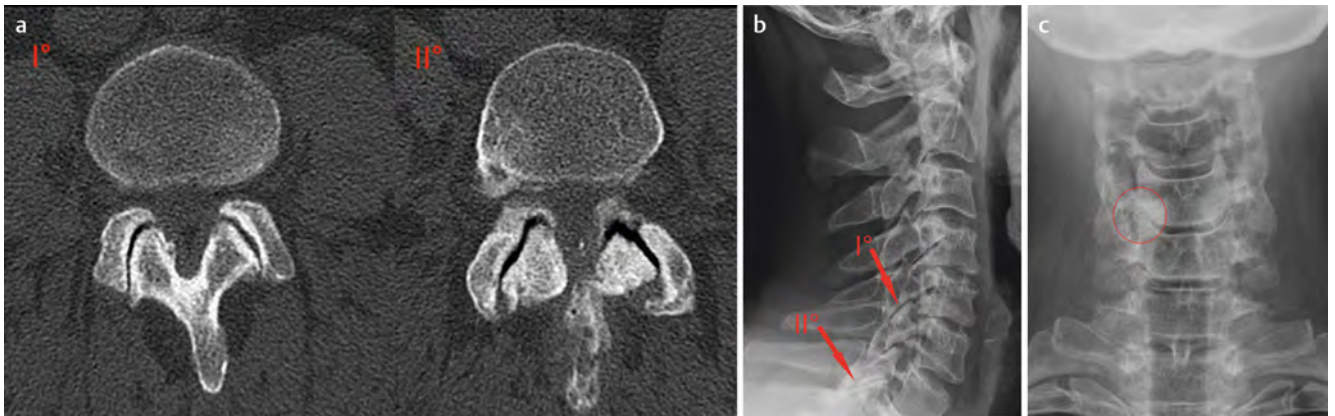
- **Fig. 3** shows the grades, and ► **Fig. 3a–e** show image examples.
- Sclerosis is an osseous reaction to an “increase in pressure due to edema” and the subsequent “loss of the buffer function” of the intervertebral disc [8]: i. e., no sclerosis without chondrosis in occupational diseases (not the case in traumatology!).



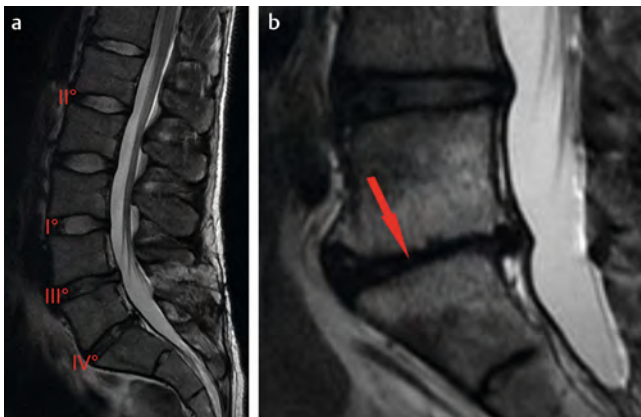
► **Fig. 3** The figure shows the typical binary image criterion of sclerosis and its stages based on the definition in the “consensus paper”. Note: In <45-year-olds, grade I sclerosis is considered not age-typical according to the consensus paper. However, since degenerative findings in the cervical spine are classified as unlikely occupational disease nos. 2108 and 2110, this differentiation is not necessary for practical use in the assessment of occupational disease nos. 2108 and 2110. Intraindividual calibration is important in the case of a visible increase in sclerosis, thus the comparison with the other visualized vertebral bodies. **a** Sclerosis grade I – cervical spine. Visible increase in sclerosis of the end plates of C5 and C6 in the case of chondrosis and spondylosis in the segment. Caution – intraindividual calibration! **b** Sclerosis grade II – cervical spine. Sclerosis of the end plates > 1 mm wide. **c** Sclerosis grade I – lumbar spine. Visible increase in sclerosis of the end plate of L3 with reduced height due to intervertebral disc damage in the segment. Caution – intraindividual calibration! **d** Sclerosis grade II – lumbar spine. Sclerosis > 2 mm wide.



► **Fig. 4** The figure shows the typical binary image criterion of spondylosis and its stages based on the definition in the “consensus paper”. The switch from age-typical to not age-typical findings is shown as follows: *cursive* = not age-typical for <50-year-olds; **bold** = not age-typical in people over the age of 50. In addition, the location makes occupational disease nos. 2108 and 2110 likely (e.g., lower lumbar spine – see consensus paper) or rather unlikely (e.g., cervical spine findings – see consensus paper). **a** Spondylosis of the cervical spine grades 1–3. Cervical spine: Grade I: 1 mm, grade II: 2–3 mm, grade III: > 3 mm. **b** Spondylosis of the cervical spine grade 4. Signs of bridging or complete bridging. **c** Retrospondylosis of the cervical spine grades 1–2.



► **Fig. 5** **a** Spondyloarthritis – lumbar spine grade I: Increased sclerosis of the vertebral joints visible. Lumbar spine grade II: Additional enlargement or outgrowths at the facet joints. **b** Spondyloarthritis – cervical spine grade I: Increased sclerosis of the vertebral joints visible. Cervical spine grade II: Additional enlargement or outgrowths at the facet joints. **c** Unvertebral arthrosis/neoarthrosis at the uncinata process.



► **Fig. 6** **a** Intervertebral disc degeneration in the lumbar spine classified as Pfirrmann I–IV. **b** Intervertebral disc degeneration in the lumbar spine classified as Pfirrmann V.

- “Intraindividual comparison” is important because it is used for “personalization” and for the differential diagnosis of constitutional variants.
- Chondrosis or a slipped disc can also be recognized without sclerosis. Sclerosis indicates a longer disease course, which must be taken into consideration in the assessment of the cause: For example, in the case of grade II chondrosis or a slipped disc but the load-bearing job ended more than 5 years ago, the causal relationship is questionable in the absence of sclerosis.

► **Fig. 3a–e** show the grades of sclerosis.

**Spondylosis (syn. spondylosis deformans), see page 8 “consensus recommendations”**

Definition: Bony overgrowths at the margins below and/or above the end plates and/or on the ventral and anterior side surfaces of the vertebral bodies. ► **Fig. 4** shows the grades, and ► **Fig. 4a–c** show image examples.

Secondary spondylosis is a particularly positive indication of occupational disease when it occurs in segments not affected by chondrosis or prolapse. As a rule, secondary spondylosis must occur in at least 2 segments, but the segments do not have to be adjacent.

The formation of spondylotic osteophytes of the thoracic spine are generally not taken into consideration.

The main pathological transformation process in an occupational disease occurs in the intervertebral disc, manifests as osseous damage in the form of a “submarginal osteophyte”, and is an expression of significant disc damage according to Dihlmann [8]. This must be taken into consideration in image analysis in order to correctly determine the causality giving rise to liability. Secondary spondylosis is significant because this is the most important finding from an epidemiological standpoint in the population of heavy workers [9].

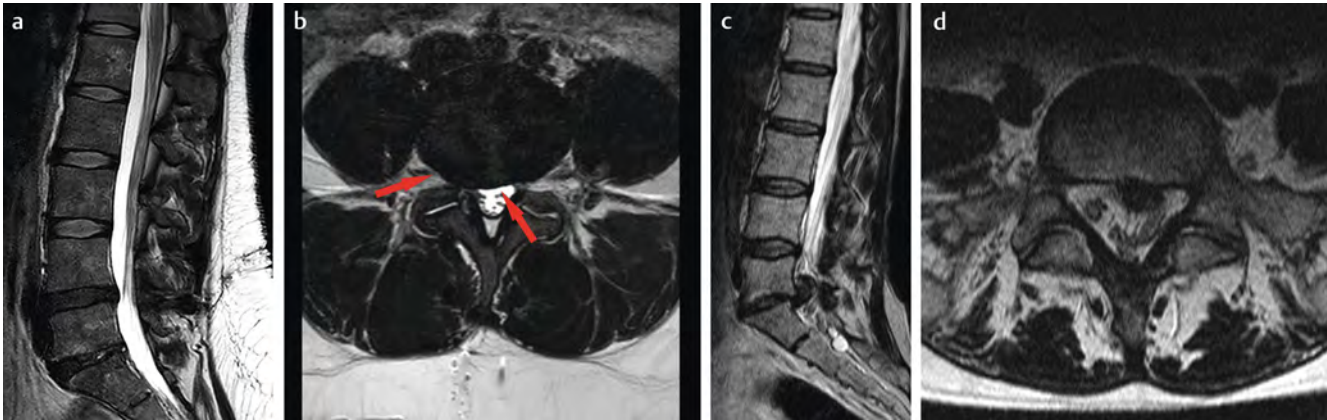
Degenerative spondylosis must be differentiated from diffuse idiopathic skeletal hyperostosis (Forestier’s disease). The excessive bone formation in diffuse idiopathic skeletal hyperostosis is an independent disease pattern. The ossifications in diffuse idiopathic skeletal hyperostosis do not affect the intervertebral disc spaces. Reduced height of the intervertebral discs is typically not seen.

It is also necessary to differentiate syndesmophytes, e. g., in ankylosing spondylitis, growing in the longitudinal direction of the spinal column from vertebral body to vertebral body. Parasyndesmophytes [8] are seen, for example, in Reiter’s disease or psoriatic arthritis. They also grow in the longitudinal direction but are only in contact with one vertebral body or grow exclusively in the perivertebral connective tissue – i. e., not submarginal-linear.

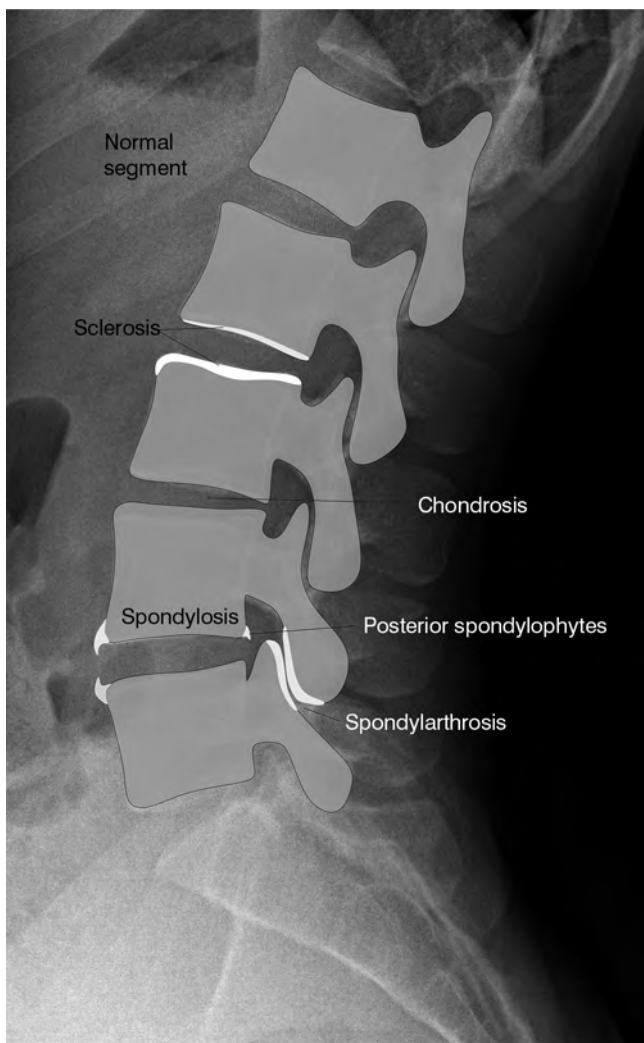
► **Fig. 4a, b** show the definition and stages of spondylosis, while ► **Fig. 4c** shows retrospondylosis.

**Retrospondylophytes (see page 9 “consensus recommendations”)**

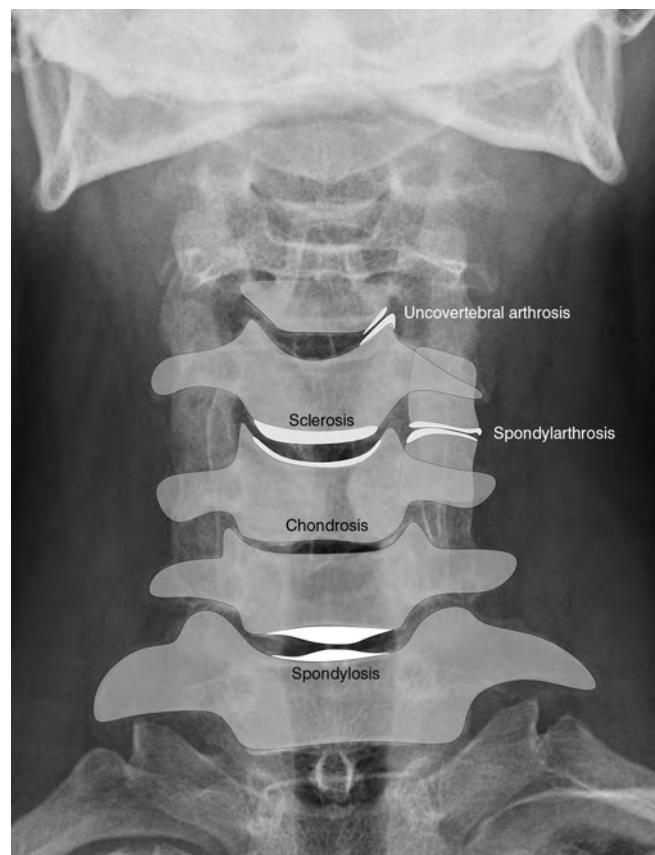
Definition: Posterior spondylophytes. The stage is determined based on tangential measurement: stage I = up to 2 mm and stage 2 = 3 mm or larger. ► **Fig. 5** shows an example.



► **Fig. 7** **a** Intervertebral disc protrusion L4/5. **b** Intervertebral disc protrusion L4/5. **c** Prolapse: Intervertebral disc displacement with cranial or caudal exceeding of the marginal contours of the vertebral body end plates on sagittal images, terminating transversely at an acute angle to the contour of the intervertebral disc. **d** Prolapse: Intervertebral disc displacement with cranial or caudal exceeding of the marginal contours of the vertebral body end plates on sagittal images, terminating transversely at an acute angle to the contour of the intervertebral disc.



► **Fig. 8** Synopsis of changes in the lumbar spine, sag.



► **Fig. 9** Synopsis of changes in the cervical spine, a. p.

## Spondyloarthritis

Definition: Degenerative changes in the vertebral joints of one or more segments of motion

The reduced height of the intervertebral disc results in a decrease in the shock-absorbing function of the disc. Spondyloarthritis can only be considered related to intervertebral disc/occupational disease when it is caused directly by a decrease in the height of the intervertebral discs. It can also occur as an independent disease pattern in polyarthritis or as a result of an asymmetrical load in transitional vertebra or scoliosis (chondrosis not required).

The grade is determined based on the extent of the sclerosis – grade I: Increased sclerosis of the vertebral joints visible. Grade II: Additional enlargement or outgrowths at the facet joints.

Image examples ▶ **Fig. 5a–c**:

## Uncovertebral arthrosis of the cervical spine

Definition: A specific arthrosis-like process of the cervical spine, neoarthrosis of the uncinat process ▶ **Fig. 5c** shows an example:

## Degeneration of intervertebral discs

### Descriptions:

A loss of signal in intervertebral discs correlates with histologically verifiable degenerative changes.

Signal loss and a lack of differentiation of the nucleus and annulus are the direct criteria for recognition required in the consensus paper.

▶ **Tab. 1** Grades of chondrosis.

Grade	Reduced height, measured in the middle	
Grade I	Lumbar spine $>/ = 1/5-1/3$	Cervical spine to $1/2$
Grade II	Lumbar spine $> 1/3-1/2$	Cervical spine $> 1/2$
Grade III	Lumbar spine $> 1/2$	
Grade IV	Lumbar spine, ankylosing chondrosis	

▶ **Tab. 2** Classification of intervertebral disc degeneration according to Pfirrmann.

Grade	Intervertebral disc structure	Differentiation of annulus/nucleus	T2 signal (MRI)	Intervertebral disc – height
I	Homogeneously white	Yes	Hyperintense	Normal
II	Inhomogeneous, possible horizontal bands	Yes	Hyperintense	Normal
III	Inhomogeneously gray	Unclear	Intermediate	Normal to slightly reduced
IV	Inhomogeneously dark gray	No	Intermediate to hypointense	Normal to moderately reduced
V	Inhomogeneously black	No	Hypointense	Collapsed

All findings > Pfirrmann III are pathological – further differentiation is not required. This is currently only possible with MRI (▶ **Table 2**).

Determination of the degree of degeneration according to Pfirrmann [10] is an additional criterion in the B-constellation of the consensus paper (see below). In light of the difficult to reproduce and thus usually unnecessary measurements for chondrosis, this “additional criterion” plays a decisive role in the recognition of occupational disease, particularly in the case of mild or moderate chondrosis.

Higher grades on MRI are used to supplement the finding or for differentiating between competing factors.

The term “black disc” is used a collective term in the literature for multiple Pfirrmann stages and should no longer be used. In addition, differentiation of higher stages is not necessary in the recognition process (Pfirrmann grade III is sufficient evidence of damage).

▶ **Fig. 6a, b** show the grades of intervertebral disc degeneration according to Pfirrmann.

## Intervertebral disc extrusion

### Definitions

#### Protrusion:

Intervertebral disc displacement without cranial or caudal exceeding of the marginal contours of the vertebral body end plates on sagittal images, terminating transversely at an obtuse angle to the contour of the intervertebral disc (▶ **Fig. 7a, b**).

#### Prolapse:

Intervertebral disc displacement with

- cranial or caudal exceeding of the marginal contours of the vertebral body end plate on sagittal images
- and/or terminating transversely at an acute angle to the contour of the intervertebral disc (▶ **Fig. 7c, d**)
- and/or with ventral dural sac compression of at least 50 %
- and/or with projection of the intervertebral disc  $>/ = 5$  mm over the posterior edge of the vertebral body.

Protrusion of more than 5 mm over the connecting line of the posterior boundary of the rear edge of the vertebral body is considered equivalent to prolapse in the assessment.



### Summary of causality test procedure via imaging

**Step 1:** Determination of the height of the intervertebral disc segment (L4/L5 and/or L5/S1 or higher)

**Step 2:** Determination of the constellation according to the consensus paper [4] (positive workplace analysis required) L4/L5 and/or L5/S1 = B-constellation, above L4/L5 = C-constellation

**Step 3:** Degree of intervertebral disc damage in the most affected segment (not typical for age vs. typical for age)

► **Fig. 8, 9** summarize the previously described findings.

### Conflict of Interest

The authors declare that they have no conflict of interest.

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