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

Part 1: Legal background, imaging diagnosis, assessment

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

Teil 1: Juristischer Hintergrund, Definitionen, Bildgebende Diagnostik und klinische Beurteilung

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ABSTRACT

Background Occupationally related limitations of earning capacity can be recognized under social legislation and may be subject to compensation ("reduction in earning capacity"). For this purpose, legislators have defined a list of occupational diseases ("BK list"). Recognition of an occupational disease requires a legal assessment procedure based on a medical appraisal. The aim of the assessment is to prove the "causality" and the "causality giving rise to liability".

Method In addition to clinical findings and workplace analyses, imaging methods (projection radiography, MRI) are primarily used to substantiate liability. These methods enable proof of load-conforming damage patterns for occupational diseases 2108/2110 (damage to intervertebral discs).

Results and Conclusion In addition to the legal background, the following review article primarily presents the image criteria for load-conforming damage patterns of the spine. On the basis of the consensus paper on the "Assessment of occupational disc diseases of the lumbar spine", image criteria are assigned to age-atypical grades of findings, and "typical constellations of findings" are defined for vibration (BK 2108) or lifting (BK 2110) loads. The aim of Part 1 is to explain the image criteria of the comparative images presented as image plates in Part 2 and thus to present a reference catalog of findings.

Key statements

- Occupational diseases are defined by legislators in the "List of Occupational Diseases".
- For occupational intervertebral disc diseases (BK 2108/2110), constellations of findings are defined.
- In the context of imaging diagnostics, a large number of image criteria are used.
- Part 1 explains the basics.
- Part 2 provides the image criteria on the basis of "comparative images" as a reference catalog.

Citation Format

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ZUSAMMENFASSUNG

Hintergrund Berufsbedingte Einschränkungen der Erwerbsfähigkeit sind im Rahmen der Sozialgesetzgebung anerkennungsfähig und ggf. schadenersatzpflichtig („Minderung der Erwerbsfähigkeit": MdE). Hierfür definiert der Gesetzgeber die Liste der Berufskrankheiten (BK-Liste). Für die Anerkennung einer BK ist ein juristisches Feststellungsverfahren erforderlich, das auf einer medizinischen Begutachtung beruht. Ziel der Begutachtung ist der Nachweis der „Einwirkungs-" und der „haftungsbegründenden Kausalität".

Methode Für die Haftungsbegründung werden neben klinischen Befunden und arbeitsplatztechnischen Analysen vor allem bildgebende Methoden (Projektionsradiographie, MR) herangezogen, die für die BK 2108/2110 (Bandscheibenschäden) den Nachweis belastungskonformer Schadensbilder ermöglichen.

Ergebnisse und Schlussfolgerung Der nachfolgende Übersichtsartikel stellt neben den juristischen Hintergründen vor allem die Bildkriterien für belastungskonforme Schadensbilder der Wirbelsäule vor. Auf der Grundlage des Konsenspapiers zur „Begutachtung von berufsbedingten Bandscheibenerkrankungen der Lendenwirbelsäule" werden Bildkriterien altersuntypischen Befund-Graduierungen zugeordnet und „typische Befundkonstellationen" bei Erschütterungs- (BK 2108) oder Hebe- (BK 2110) Belastungen definiert. Im Teil 1 werden Erläuterung zu den im Teil 2 illustrierten Bildkriterien der Vergleichsbilder gegeben. Diese dienen als Grundlagen des Befund-Referenzkatalogs.

Introduction

According to social legislation (German Social Code IV and VII), occupationally related limitations of employability (see the list of occupational diseases [1]) are monitored on a preventative basis and compensated if applicable upon confirmation.

The recognition or rejection of an occupational disease is a legal assessment procedure [2, 3] based on a medical evaluation of the insured person [4, 5]. This correlation test includes clinical and imaging evaluation criteria as evidence [6]. The goal of this test is to prove a relationship between the insured activity and the damaging effects (causality/German Social Code VII, § 9) and between this damage effect and the occupational disease (causality giving rise to liability/German Civil Code BGB; § 823 paragraph 1 [7]).

The main basis for evaluating causality giving rise to liability is diagnostic imaging as "proof based on inspection" [8] and is thus part of the evaluation of the "List of Occupational Diseases 2108/2110" (see German Social Code VII § 7/paragraph 1 [9] and § 9/paragraph 2 [10]: List of occupational diseases: OD no. 2108: occupational diseases of the lumbar spine "caused by carrying, lifting, or extreme trunk flexion"; OD no. 2110: occupational diseases of the lumbar spine "caused by vertical whole-body vibration").

There is a two-part consensus paper [4] regarding the "medical evaluation criteria for occupational diseases of the lumbar spine related to the intervertebral disc" from the year 2005 that summarizes the "medical evaluation criteria" (clinical finding, work history, imaging findings) and thus provides guidelines [11] for the interdisciplinary expert opinion process.

Goal

Part 1 provides clinical and procedural information for the interdisciplinary expert opinion process and recommendations for quality assurance.

The goal of the image reference material (part 2) is to support image evaluation in the medical expert opinion for OD nos. 2108 and 2110 with comparative image analysis and to substantiate the image criteria and classifications of findings specified in the consensus paper in a reproducible manner.

Imaging

Basic information

The basis of the medical expert opinion in the legal assessment procedure for occupational diseases no. 2108 and 2110 is the case-based determination of a "constellation of findings" that can be reproduced by a physician (e. g., consensus constellation A, B, or C [4]).

Diagnostic imaging is used to prove or rule out "load-conforming damage patterns" of the lumbar spine (OD nos. 2108 and 2110).

In contrast, any claims for damages relating to a "limitation of earning capacity" (= liability in damages; German Civil Code § 823 paragraph 1 [7]) **are evaluated in a separate, clinical expert opinion and are not the goal of diagnostic imaging.**

In the scope of validity of German Social Code VII (statutory accident insurance bears responsibility:), claims for compensation

or damages are based as a rule on the possible reduction in earning capacity. In contrast to private accident insurance, it is not about a loss of function [12] compared to the norm as a result of verified organ damage (e. g., intervertebral disc damage).

The purpose of diagnostic imaging in the assessment procedure regarding OD nos. 2108 and 2110 is the reproducible and provable detection (X-ray, MRI) of visible morphological criteria of chondrosis, sclerosis, spondylosis, spondylarthrosis [13], and typical intervertebral disc changes [14, 15].

Comparison images for systematic image analysis

The decisive qualitative requirement regarding proof and grading of findings in the assessment of occupational diseases is their reproducibility [16, 17].

From the standpoint of diagnostic imaging,

- both **standardized examination conditions** ([17] MRI protocols of the musculoskeletal system imaging work group of the German Radiological Society – homepage) and
- **image assessments that can be used as expert opinions, i. e., are verifiable,** are needed for this. **Systematic image analysis** [17] and **structured reporting** (DIN 6827-5; [18]) are available for this purpose.

Examination technique and protocols

The imaging method or combination of methods is selected based on the clinical issue or object of the expert opinion [3, 8] and the target organs to be visualized.

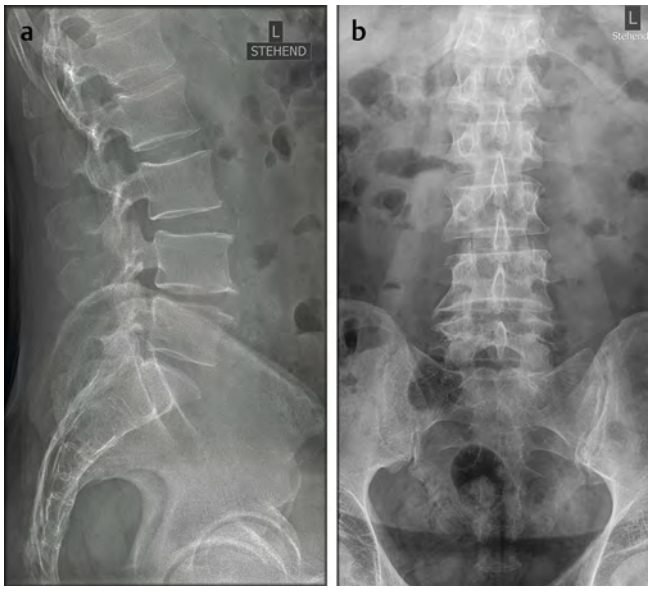
This can prove the justifying indication (§ 83, paragraph 3 of the Radiation Protection Act [19] and § 119 of the Radiation Protection Ordinance [20]), which does not correspond to a clinical (§ 83, paragraph 1.1 [19]) but rather a "social" (§ 83, paragraphs 1.2 and 2 [19]) indication in the framework of the expert opinion, i. e., the examination is in the economic interest of the insured.

The assessment of occupation-related damage to the spine focuses on work-related exposure of the vertebral bodies and facet joints and the intervertebral discs (see the Mainz-Dortmunder dose model "MDD").

It relates to the detection of damage patterns, with their detection, severity, and combination being assigned a load-conforming degree [4, 21].

Spinal imaging on 2 planes (projection radiography) is used for diagnostic imaging [17]. The relevant bone structures and the *secondary criteria* of intervertebral disc damage (chondrosis, sclerosis) can be visualized. Alternatively, superimposition-free computed tomography (CT) with uniplanar secondary reconstructions can be used. However, this is not usually the initial diagnostic method.

Magnetic resonance imaging (MRI) of the spine, particularly the lumbar spine, is used to image the *direct criteria* of intervertebral disc damage [14, 15] and is therefore recommended as the method of choice to verify the "constellation of findings" ([4] "e-constellations").



▶ **Fig. 1** Radiograph of the lumbar spine on two planes with degenerative changes in terms of spondylosis and degenerative changes of the facet joints in a 55-year-old patient.

Projection radiography

The high contrast of bone allows comprehensive visualization of the contour and structure.

Images on two planes are needed to visualize the target organs (cervical spine, thoracic spine, lumbar spine) with respect to the intervertebral distance (see ▶ **Fig. 1a, b**), the vertebral end plates, any osteophytic spurs (spondylosis), and the facet joints (▶ **Fig. 1a, b**) three dimensionally with projection radiography.

The findings specified in the consensus paper on OD nos. 2108 and 2110 [4] (chondrosis, spondylosis, and spondylarthrosis) can be classified according to the degrees of severity defined there based on radiography on two planes. The findings must additionally be divided into "typical for age" and "not typical for age" [4].

To ensure the necessary level of image quality, precise lateral and a. p. images are required. The divergent central X-ray should only show the unavoidable minimum (at L1 and L5) projection-based geometric distortion of the latero-lateral overlapping edges of the vertebral bodies.

The ongoing discussion regarding imaging in a standing or lying position is unnecessary for the evaluation of findings. To date, orthopedists [21] have favored images in a standing position as a more physiological representation of the intervertebral spaces (e. g., chondrosis).

However, due to patient movements during positioning adjustments and X-ray acquisition in the standing position, a potential "quantitative finding" cannot be separated from this based on image analysis. Moreover (see below), distance measurements are performed at the midline height of the vertebral body (e. g., Hurxthal I or II [22, 23]) and are taken into consideration in the assessment of the findings semiquantitatively and intraindividually exclusively on a relative basis.

Some findings acquired exclusively in a standing position are not morphologically fixed and consequently cannot substantiate

an independent portion of load-conforming damage. **Therefore, radiographs of the spine in a lying position are recommended.**

Settings, patient positioning [17], and image labeling [24] are important particularly with respect to radiation hygiene and measurement accuracy. In addition, the expert opinion should be provided by experienced experts.

For standards and quality reasons, digital documentation techniques (e. g., the flat detector technique) in the case of X-ray acquisition should be used exclusively. In particular, use of an exact collimation technique [25] should be ensured (▶ **Fig. 1**).

Magnetic resonance imaging (MRI)

The main focus of MR imaging with regard to an expert opinion on OD nos. 2108 and 2110 is intervertebral disc findings and subsequent changes in the vertebral bodies.

On the one hand, degenerative intervertebral disc damage should be graded [14] and on the other hand, any herniations (extrusions [15]) should be differentiated (protrusion vs. prolapse). The goal of MRI examinations according to the consensus paper is the direct detection of intervertebral disc damage (chondrosis, protrusion, prolapse) and secondary reactions involving the bone of the vertebral body (sclerosis, spondylophytes, spondylarthrosis).

The cervical spine should be examined from the base of the skull to T3 and the lumbar spine from T12 to the sacral bone (iliosacral joint) with sag. T1-TSE, sag. T2-TSE with fat saturation, ax. T2-TSE, and cor. PD sequence. Alternatively, a sag. T2-TSE 3D sequence can be used (protocol recommendations of the musculoskeletal imaging work group of the German Radiological Society).

Reporting

Imaging

Projection radiography

Every radiographic examination requires a written report (§ 85, paragraph 4 of the Radiation Protection Act [26]) by a physician with specialist or sub-specialist knowledge (§ 30 of the Radiation Protection Ordinance [27]; German regulations regarding licensing for the use of ionizing radiation in medicine 3.1. and Appendix F). This is part of the examination documentation.

According to the subject of the expert opinion (see above), the distances between the vertebral bodies (chondrosis), the thickness of the vertebral end plates (sclerosis), the formation of osteophytes (spondylosis) including the optional digital measurement of spondylophytes and changes in the facet joints (spondylarthrosis) should be recorded already during initial reporting and be documented in the report/evaluation text.

The bone diagnostic criteria are recorded by **systematic image analysis**. This is defined as imaging of the contour and structure of the target organs examined with imaging (X-ray, MRI) – in the case of OD nos. 2108 and 2110 this means imaging of the vertebral bodies and facet joints and in the case of MRI the intervertebral discs.

The image criteria are checked and documented with respect to their detection ("present") or exclusion ("not present"). This yes/no determination is a **binary decision process**.

We suggest calling image criteria for which a binary decision algorithm (present/not present) can be used and which can thus be used for quality assurance particularly in the evaluation of reproducibility "**binary criteria**" and giving them preference for systematic image analysis.

In quantitative terms, the findings are included in the constellation of findings solely semiquantitatively (e. g., less than <, equal to =, greater than >) according to the specifications in the consensus paper [4].

A millimeter-based measurement is not necessary for chondrosis (intervertebral distance), sclerosis (thickening of the end plates), and spondylarthrosis (sclerosis and hyperostosis of the small facet joints) since in principle a measurement does not affect the detection/exclusion of these image criteria and thus the constellation variants. Measurements can support the semiquantitative categorization of findings and should be performed at the midline height of the vertebral body (in the ventro-dorsal middle of the end plates) according to Hurxthal [28] (see ▶ **Fig. 2a–c**).

In the case of vertebrae that are not scanned at right angles, the Hurxthal II measurement method [28] should be used. If the vertebral end plates appear as oval surfaces, the height of the intervertebral disc corresponds to the distance between the midlines of these ellipsoidal surfaces (▶ **Fig. 2c**).

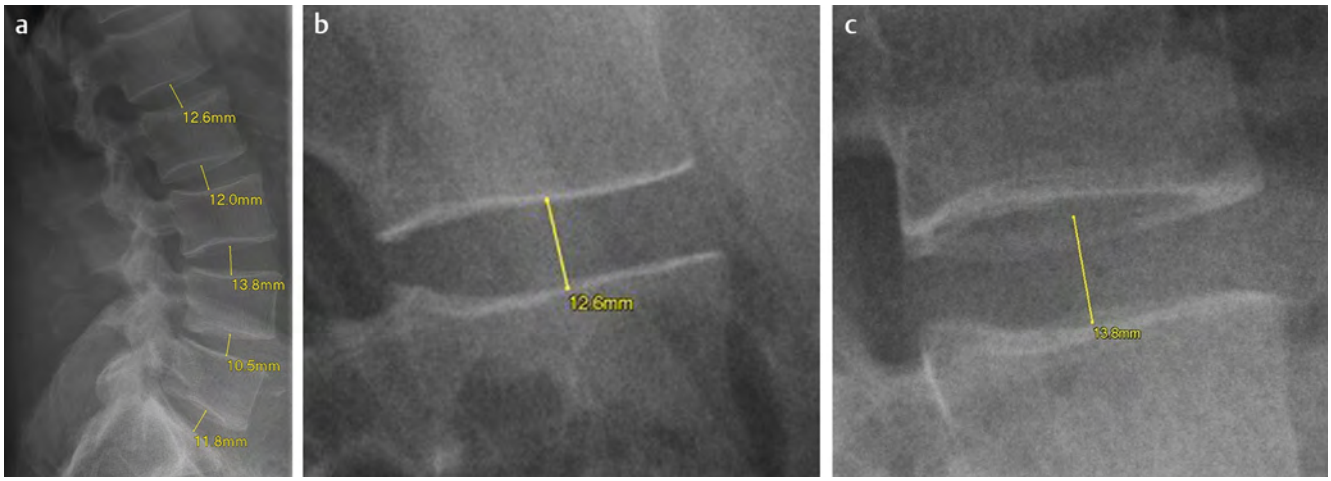
Moreover, an intraindividual comparison to the segments with non-pathological changes is possible on MRI. The individual extent of the "load-conforming damage pattern" can be determined and sufficiently quantified [4].

See ▶ **Table 1** for an example of Excel-based input of measurement results and their interpretation.

Magnetic resonance imaging (MRI)

Reporting of MRI examinations in the assessment procedure for a "load-conforming damage pattern" with respect to occupational disease nos. 2108 and 2110 should meet the following schematic requirements:

1. Systematic image analysis of all vertebral structures regarding any inflammatory, degenerative (e. g., spinal canal stenosis), and tumorous findings or pathological fractures is performed. **Competing factors** can be thus ruled out or included in considerations of the cause.
2. According to the consensus paper, intercorporeal intervertebral disc damage should be classified.
   Note:
   With respect to the Mainz-Dortmunder dose model [6], in addition to the use of projection radiography to differentiate between chondrosis grades I and II, MRI can be used as a threshold indicator to determine if the damage is above or below Pfirrmann grade III. According to the occupational diseases, this expert evaluation of chondrosis is of paramount interest. MRI is used to provide additional details to the radiographic finding.
   The term "black disc" is sometimes assigned to Pfirrmann stage IV and/or V in the literature. However, this categoriza-



▶ **Fig. 2 a** Measurement of the intervertebral disc height on the radiograph as an indirect criterion of chondrosis; **b** Enlarged section of image from **a** with the correct rectangular spine projections. The measurement should be performed in the middle of the vertebral end plates. **c** Image without the correct rectangular spine projections. The intervertebral disc height corresponds to the distance between the midlines and the ellipsoidal surfaces.

tion is not necessary and should not be performed for the "constellations of findings" according to the consensus paper.

3. In the case of intervertebral disk herniation, also referred to as extrusion, a differentiation should be made in the expert opinion between protrusion and prolapse – see below [15, 29].

Clinical criteria

Chronic or chronic recurring symptoms and functional limitations must be present. According to the regulation justification of the federal government (publication no. 19/17586 of the German Parliament, pg. 134 [30]), back problems in their general form do not constitute an occupational disease.

Practical approach to causality test via imaging:

- **Step 1:** Determination of the segment height of the intervertebral disc damage (L4 / L5 and/or L5 / S1 or cranial)
- **Step 2:** Determination of the constellation according to the consensus paper [4] (prerequisite: positive workplace analysis) 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)

Subsequent steps take into account any competing factors and are a primary task of the clinical assessment.

Work-related investigations, clinical criteria, causality test via imaging

Work-related investigations

Recognition of OD nos. 2108 and 2110 typically requires at least 10 years of work associated with regular lifting and carrying of heavy loads or work in spaces less than 100 cm or in a bent posture of 90° or more.

Therefore, for example, a compressive force on L5 / S1 of 3.2 kN is reached when lifting a load of 20 kg with both hands.

In the case of an extremely bent posture, pressures of 1.7 kN are reached.

While only daily doses of 5.5 kNh and higher were taken into consideration until 2007, this cut-off value was omitted with the judgment of the Federal Social Court dated 10/30/2007 (B 2 U 4/06 R) [31]. Moreover, not the double dose of 25×10^6 Nh but rather the "lower cut-off value" of 12.5×10^6 Nh is considered sufficient as the requirement for a dangerous total load.

Conclusion

a) Recognition of an intervertebral disc disease in accordance with the regulation regarding OD nos. 2108 and 2110 requires a pathological ("not typical for age") imaging finding of the intervertebral disc (direct and/or indirect image criteria – part 1) and a corresponding clinical picture.

b) According to the consensus recommendations, detection of intervertebral disc damage on imaging is essential but is not sufficient for proving an intervertebral disc disease. Correlating clinical symptoms must also be present since pathological intervertebral disc changes can remain asymptomatic. Moreover, untested linking of subjective diffuse back problems to positive imaging findings is not allowed.

c) Evidence of an (at least) highly probable relationship between the functional disorder or symptoms and the affected segments is required. It is therefore necessary to correctly allocate the segment finding on image analysis to the spinal segments and thus the neurological pattern of findings (e. g., disc damage L4/5 and pain symptoms in dermatome L4).

d) The recognition procedure requires a structured and reproducible image evaluation by a radiology specialist. Systematic image analysis using binary finding criteria and their grading are recommended. This is the basis of the alphanumeric constellations of findings defined in the consensus recommendations. The causality test performed as part of the

▶ **Table 1** Excel table for the measurement of the intervertebral disc height The program uses a correction factor based on the relative height differences of the intervertebral discs [22].

Segment	L1/2	L2/3	L3/4	L4/5	L5 / S1
Intervertebral disc height in mm	**12.6**	**12.0**	**13.8**	**10.5**	**11.8**
Correction factor	1.26	1.13	1.05	1	1.16
Corrected intervertebral disc height	15.876	13.56	14.49	10.5	13.688
Largest corrected disc height	15.876	15.876	15.876	15.876	15.876
Standardized relative intervertebral disc height (rounded)	**100 %**	**85 %**	**91 %**	**66 %**	**86 %**
Based on measured intervertebral disc height minus 0.5 mm*	**96 %**	**82 %**	**88 %**	**63 %**	**83 %**
Based on measured intervertebral disc height plus 0.5 mm*	**100 %**	**89 %**	**95 %**	**69 %**	**90 %**
Interpretation	**No chondrosis**	**No chondrosis**	**No chondrosis**	**Chondrosis grade I**	**No chondrosis**
Caution: The results can only be interpreted after all available intervertebral heights have been input!					
*Note: Based on the accuracy of the measured intervertebral height of +/– 0.5 mm, the specified "fluctuation range" of the standardized relative intervertebral disc height should be taken into consideration in the expert assessment. The interpretation of the degree of chondrosis is based on the following assessment of the standardized relative intervertebral disc height:					
	No chondrosis:		> 80 %		
	Chondrosis grade I:		> 66 to 80 %		
	Chondrosis grade II:		> 50 to 66 %		
	Chondrosis grade III:		< = 50 %		

recognition procedure is based on image findings, clinical findings, and the workplace analysis.

e) The comparison images presented in part 2 and instructions provided in the consensus paper regarding OD nos. 2108 and 2110 are used for quality assurance in the expert opinion procedure.

Conflict of Interest

The authors declare that they have no conflict of interest.

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