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RESEARCH

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Considering hounsfield units in native CT-scans for diagnosing spondylodiscitis

Max Prost^{1*}, Roman Taday¹, Christian Bernard Matar¹, David Latz¹, Christoph Beyersdorf¹, Melanie Elisabeth Röckner¹, Joachim Windolf¹ and Max Joseph Scheyerer¹

Abstract

Background The significance of native Computer tomography (CT) Scans as an alternative diagnostic tool beside Magnetic Resonance Imaging (MRI) for spondylodiscitis is poor according to the current data. CT Scans are currently reserved to analyze the bony destruction and for settings in which performing an MRI is contraindicated. Therefore, the aim of this study was to investigate, whether spondylodiscitis leads to a significant pattern of the density distribution from the affected vertebral bodies and discs measured by Hounsfield Units (HU) in native CT Scans. Such a parameter would be a useful tool to aid in the early diagnosis of spondylodiscitis using CT.

Methods In a retrospective study we analyzed data from 136 patients, who were treated for spondylodiscitis. Patients who provided MRI- and CT- scans of the spine were included. In axial CT planes HU from the affected intervertebral disc as well as from the affected vertebral bodies and from the unaffected adjacent intervertebral discs and vertebral bodies from the level above and below as reference were measured.

Results The average measured HU of the affected disc were 26.0% less than in the not affected adjacent discs ($p < 0.001$). The average measured HU of the affected vertebral bodies were 33.77% higher than in the not affected adjacent vertebral body's ($p < 0.001$). These findings are independent from the affected part of the spine (e.g. cervical, thoracic or lumbar) and from the degree of bony destruction according to Eysel-Peters classification.

Conclusion A reduction in the HU of the affected intervertebral disc by approximately 25% and/or an increase in the HU of the affected vertebral bodies by approximately 30% compared to the adjacent intervertebral discs or vertebrae indicates spondylodiscitis even in the early stages without destruction and regardless of the location.

Keywords Spondylodiscitis, Diagnostics, Spinal infections, Hounsfield units

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Introduction

Infections of the spine like spondylitis or spondylodiscitis are rare, but still the third most common form of osteomyelitis. Magnetic Resonance Imaging (MRI) remains the gold standard imaging in depicting spondylodiscitis, offering a high sensitivity and specificity. Nevertheless, acquiring high-resolution images through MRI can sometimes be difficult, due to long acquisition time, patient-related contraindications or other logistic issues like access or availability [1, 2]. Alternatively, native or contrast-enhanced computed tomography (CT) is widely accessible and enables faster assessment than MRI and represents the modality of choice for the detection of differential diagnoses of spondylodiscitis with a higher incidence (e.g. osteoporotic fractures or degenerative osteochondrosis) [3, 4]. Spondylodiscitis is characterized by a heterogenic clinical presentation with non-specific signs and symptoms on presentation especially at the early stage of the disease accompanied by a variety of differential diagnoses and is therefore often recognized and treated late. Recent studies have estimated the delay between the onset of the non-specific symptoms and the diagnosis of spondylodiscitis to an average of 45 days [5]. This leads to an increased morbidity of the disease and can even become life threatening [6]. During the early stage of disease in some cases conventional imaging modalities like x-ray can fail to detect subtle changes in vertebral and non-bony surrounding structures [7]. Actually, MRI is known as the best diagnostic tool especially for early spondylodiscitis [6]. But even in MRI it could be difficult to distinguish in early state of the disease between osteochondrosis and spondylodiscitis or between spinal neoplasms and spondylodiscitis [8–12]. Additionally, the indication for obtaining early MRI in a patient with back pain is tied to reasonable suspicion of spondylodiscitis or red flags [8, 13]. In terms of initial diagnostic imaging for spondylodiscitis, CT scans are currently reserved to analyze the bony destruction and for settings in which performing an MRI is contraindicated, and more expensive nuclear imaging (PET/CT) is not feasible [8, 14, 15]. This is caused by the fact, that its accuracy remains significantly lower than MRI and PET/CT, particularly in early stages. CT is currently used mostly for percutaneous needle biopsy and drainage of abscesses [6, 8, 16, 17]. Nevertheless, measuring local bone quality using CT scans with Hounsfield units (HU) quantification is possible and has been shown to be a reliable method to assess bone density changes for osteoporosis, spondylarthritis and osteochondrosis across all vertebrae [18–21].

HU is a quantitative scale for describing radiodensity which is frequently used in CT scans. In this scale the radiodensity distilled water at standard pressure and temperature is defined as 0 HU, while the radiodensity

of air at standard pressure and temperature is defined as −1000 HU [22, 23]. Exact HU dynamics can vary from one CT acquisition to another due to CT acquisition and reconstruction [24].

The aim of the present study was to analyze an alternative method to diagnose spondylodiscitis with a native CT scan. To assess this aim, we want to show whether the measured HU in the infected intervertebral discs and vertebral bodies, in comparison to adjacent non infected spine segments display a significant pattern to be interpreted as a reliable parameter that can predict an infectious entity of the spine. Such a parameter would be a useful tool to aid in the early diagnosis of spondylodiscitis using CT.

Patients and Methods

We performed a retrospective single center data analysis. An existing database of patients who were treated with spondylodiscitis in our institution from 2014 to 2022 was screened for patients who met our inclusion criteria. We included patients in whom the diagnosis of spondylodiscitis was ensured by MRI, laboratory examination and positive pathogen detection whether with needle guided or intraoperative biopsy or with blood culture and who had a CT scan of the affected spine segment. Patients with tuberculous spondylodiscitis were excluded from our investigation. Patients who did not have an MRI of the spine and patients without a CT or with an incomplete CT examination of the spine were excluded. The maximal accepted time between MRI and CT scan was 14 days, if the time between imaging was longer the patients were excluded. Further, we excluded patients from the study who developed spondylodiscitis after spinal surgery in which implants such as screws, rods or cages were inserted, provided that these implants were still in the body.

Demographical data like sex and age as well as data according to the localization of the spondylodiscitis were recorded. The radiological degree of destruction caused by the spondylodiscitis was detected and classified according to the Eysel-Peters Classification [25]. The native spinal CT and MRI were analyzed by the IDS 7-PACS®-System (Sectra, Linköping, Sweden). The affected intervertebral discs and vertebral bodies were identified in the available MRI of the patients. For HU measurement we used a three-dimensional multiplanar reconstruction of the respective spine-CT. To analyze the changes of the intervertebral disc, we measured the HU in axial CT-planes from the affected intervertebral disc (identified in the MRI) and from the adjacent unaffected intervertebral discs one level above and below who served as reference (Figs. 1 and 2). For analysis of the vertebral body, we measured the HU from the vertebral bodies which were affected by the spondylodiscitis

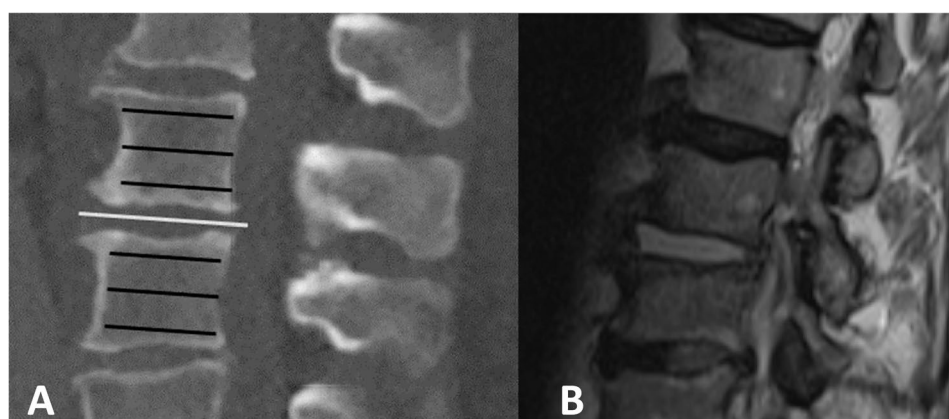


Fig. 1 Localization of the performed measurements. **A** shows a lateral reconstruction of a lumbar spine CT Scan. In the available T2 MRI Sequence (**B**) of this patient the intervertebral disc between L2 and L3 showed inflammatory changes. This disc was classified in the CT (**A**) as an affected disc (white bar). The intervertebral disc one segment above and one segment below served as reference. The black bars show the localization of the performed measurements in the vertebral bodies which were affected by the spondylodiscitis. The unaffected adjacent vertebral bodies from the level above and below as reference

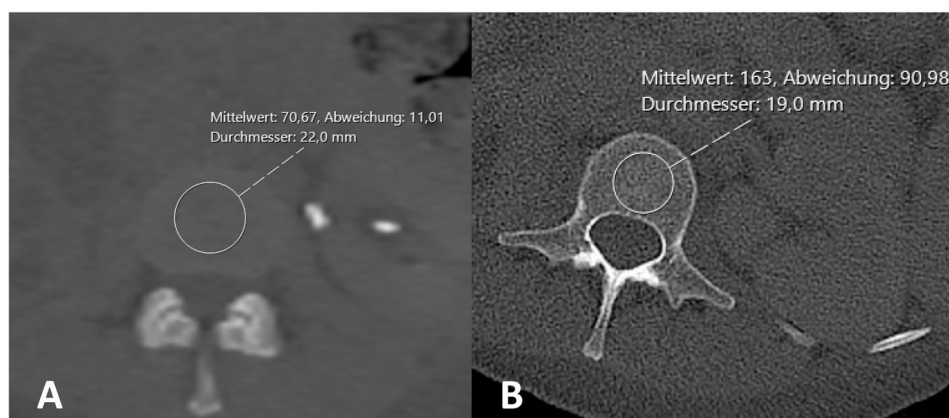


Fig. 2 Measurement of the HU in the vertebral discs and the vertebral bodies. Axial reconstruction of a lumbar spine CT Scan. A circular region of interest was selected based on manually defined reference lines, having a diameter of app. 75% of the anteroposterior and transverse diameters of the vertebral body or the intervertebral disc. The average HU within the sample region was displayed by the software (Mittelwert). A shows exemplary a performed measurement in a vertebral disc – HU 70.67. B shows a performed measurement in a vertebral body – HU 163

(above and below the affected intervertebral disc) and the HU from the unaffected adjacent vertebral bodies from the level above and below as reference. HU measurement of the vertebral bodies was taken at from three cross-sectional slices at the level of the cover plate, in the middle of the vertebral body and close to the ground plate (Fig. 1).

The mean of these three measurements was calculated and analyzed. In the axial CT- planes a circular region of interest was selected based on manually defined reference lines, having a diameter of app. 75% of the anteroposterior and transverse diameters of the vertebral body or the intervertebral disc (Fig. 2).

The average HU within the sample region was displayed by the software. The measurements were performed according to the technique described by Schreiber et al. in 2011 [14].

Statistical analysis

Statistical analysis was performed by SPSS® 27 (IBM, Armonk, USA). Descriptive data are given as mean and standard deviation (SD). We tested all continuous variables for normal distribution by Kolmogorov–Smirnov test. Variables that showed normal distribution were analyzed by t-test and variables, which showed no normal distribution, were analyzed by Wilcoxon signed-rank test.

This study was approved by the local ethics committee (Register number 2020–914_1) and was conducted according to the revised Declaration of Helsinki.

Results

From the 246 patients with spondylodiscitis in our database we identified 136 patients who met our inclusion criteria. 110 patients could not be included due to

Table 1 Measured HU of the affected and unaffected adjacent vertebral disc depending on the Eysel- Peters classification

	Affected disc Type EP 1	Unaffected adjacent disc Type EP 1	Affected disc Type EP 2	Unaffected adjacent disc Type EP 2	Affected Disc Type EP 3	Unaffected adjacent disc Type EP 3
Mean	71.9	96.6	74.7	102.5	73.9	97.4
SD	30.3	23.2	29.9	30.4	26.0	24.2
Significance	$p < 0.001$		$p < 0.001$		$p < 0.05$	

Table 2 Measured HU of the affected and unaffected adjacent vertebral bodies (VB) depending on the Eysel- Peters classification

	Affected VB Type EP 1	Unaffected adjacent VB Type EP 1	Affected VB Type EP 2	Unaffected adjacent VB Type EP 2	Affected VB Type EP 3	Unaffected adjacent VB Type EP 3
Mean	236.0	178.1	241.4	184.6	284.7	199.2
SD	93.1	68.6	67.3	63.5	71.5	57.7
Significance	$p < 0.001$		$p < 0.001$		$p > 0.05$	

Table 3 Measured HU of the unaffected and not affected adjacent vertebral disc depending on localization

	Affected disc cervical spine	Unaffected adjacent disc cervical spine	Affected disc thoracic spine	Unaffected adjacent disc thoracic spine	Affected disc lumbar spine	Unaffected adjacent disc Lumbar spine
Mean	94.7	115.4	81.2	108.5	63.0	87.7
SD	33.5	21.3	31.5	26.9	24.7	19.4
Significance	$p < 0.005$		$p < 0.001$		$p < 0.001$	

Table 4 Measured HU of the affected and unaffected adjacent vertebral bodies (VB) depending on the localization

	Affected VB cervical spine	Unaffected adjacent VB cervical spine	Affected VB thoracic spine	Unaffected adjacent VB thoracic spine	Affected VB lumbar spine	Unaffected adjacent VB Lumbar spine
Mean	362.4	271.3	266.9	81.6	211.4	166.6
SD	73.2	50.5	195.6	62.4	64.6	60.5
Significance	$p < 0.05$		$p < 0.05$		$p < 0.001$	

incomplete set of radiological data or due to postoperative spondylodiscitis.

44 patients were female (32.4%), 92 patients were male (67.6%). The average age of the patients was 66.86 (13.08) years. 9 (6.6%) patients had a spondylodiscitis located in the cervical spine, 50 (36.8%) were located in the thoracic and 77 (56.6%) in the lumbar spine.

According to the Eysel-Peters Classification 57 (41.9%) patients were classified as type 1, 55 (40.4%) as type 2 and 24 (17.6%) as type 3.

The average measured HU of the affected disc were 26.0% less than in the unaffected adjacent discs (73.4(29.2) vs. 99.1 (26.5)). The difference was significant ($p < 0.001$).

The average measured HU of the affected vertebral bodies were 33.8% higher than in the unaffected adjacent vertebral body's (246.8 (81.2) vs. 184.5 (64.7)). The difference was significant ($p < 0.001$).

In a subgroup analysis in which we analyzed the difference of the measured HU from the affected discs and vertebral bodies depending on the Eysel-Peters Classification, the measured HU of the affected disc were significant less than in the unaffected adjacent discs independent of the Eysel-Peters type. The measured parameters for the discs were shown in Table 1.

The measured HU of the affected vertebral bodies were significantly higher than in the unaffected adjacent

vertebral bodies in patients with a spondylodiscitis type Eysel-Peters 1 and 2. In the patients with a type 3 spondylodiscitis, the difference was not significant. The measured parameters for the vertebral bodies were shown in Table 2.

In a further subgroup analysis, we analyzed the difference of the measured HU from the affected discs and vertebral bodies depending on the localization of the spondylodiscitis. The measured HU of the affected discs were significantly less than in the unaffected adjacent discs independent of the localization. The measured parameters for the discs were shown in Table 3.

The measured HU of the affected vertebral bodies were significantly higher than in the unaffected adjacent vertebral bodies independent of the localization. The measured parameters for the vertebral bodies were shown in Table 4.

Discussion

Through the analysis of CT scans from 136 patients, this study demonstrates that the average measured HU of the affected intervertebral disc was 26.0% lower than that of the unaffected adjacent discs ($p < 0.001$). The average measured HU of the affected vertebral bodies was 33.77% higher than that of the unaffected adjacent vertebral bodies ($p < 0.001$). These findings were independent of the affected spinal segment (e.g., cervical, thoracic, or lumbar

spine) and the degree of bone destruction according to the Eysel-Peters classification.

MRI remains the gold standard in the early detection of spondylodiscitis due to its high sensitivity and specificity [14, 26]. However, CT imaging is more widely available and remains the first-line imaging modality for patients presenting with unspecific spinal symptoms in depicting differential diagnoses, particularly when MRI is contraindicated or unavailable [8]. A justified indication for obtaining early MRI in a patient with back pain is obligatory tied to a reasonable suspicion of spondylodiscitis or red flags, due to high cost, long acquisition time or patient-related contraindications (non-MR-capable pacemakers, other patient-dependent factors) [8, 13, 26]. Although inaccuracies related to geometry and basic radiation physics principles (i.e. noisy images, variability in axial slices) exist, the value of the HU measurements appear to be a reliable predicting bone mineral density changes of trabecular bone and the density of intervertebral disc [19, 20, 27]. Prior studies have demonstrated that HU values in CT imaging positively correlate with bone mineral density, especially of vertebral endplates [19, 20, 27, 28]. Our findings align with these studies and add further evidence that HU changes in both vertebral bodies and intervertebral discs can serve as indicators of pathological changes in spondylodiscitis. The presence of spondylodiscitis is often indistinguishable from osteochondrosis on native radiologic imaging [15, 29]. Previous studies have shown inconsistent changes in HU values in degenerative disc disease, with a tendency toward reduced HU values in adjacent vertebral bodies as degeneration progresses, supporting the value of HU differentiation in inflammatory versus degenerative conditions [21, 27, 29–32].

Compared to the unaffected adjacent vertebral sections, the observed decrease of HU values of the affected discs accompanied by increased HU values of the affected vertebral bodies, indicate a pathophysiological pattern of disc destruction with secondary reactive osteosclerosis of the adjacent vertebral bodies in spondylodiscitis. These findings were particularly evident in early disease stages like Eysel I and II, likely corresponding to infection-triggered inflammatory processes and reactive bone marrow changes [33]. Due to the fact, that especially in this early stage of the disease, it could be difficult to distinguish between osteochondrosis and spondylodiscitis even in an MRI, the results of our investigation present an important diagnostic tool to improve diagnosing spondylodiscitis. In contrast, in more advanced stages (e.g., Eysel III), the variability and extent of vertebral destruction and reactive bony bone formations may lead to a heterogeneous HU distribution, which may explain the reduced statistical significance of HU differences in later disease stages. A major strength of this study is the

relatively large cohort and standardized analysis of HU values across different spinal segments and disease severities. The study presents a novel, quantitative, and widely available diagnostic indicator that may assist in the early detection of spondylodiscitis.

It must be emphasized, however, that this study only included patients with pyogenic spondylodiscitis. Therefore, the results observed cannot necessarily be extrapolated to other forms of spondylodiscitis, particularly those caused by tuberculosis. This is particularly due to the fact that spondylodiscitis caused by tuberculosis usually results in bone destruction without new bone formation, whereas pyogenic spondylodiscitis is usually accompanied by new bone formation after bone destruction.

However, this is a retrospective, single-center study, which limits the generalizability of the results. There was no direct comparison group with osteochondrosis, and no conclusions can be drawn regarding diagnostic accuracy measures such as sensitivity or specificity.

However, these findings support the hypothesis that HU measurements on native CT scans can help differentiate early spondylodiscitis from degenerative changes, particularly when MRI is not feasible. In such cases, the combination of reduced disc HU values, increased vertebral body HU values, and elevated inflammatory markers as well as clinical red flags (e.g., CRP, leukocytosis, ESR) [6, 8, 15] may strengthen the clinical suspicion of spondylodiscitis and justify expedited MRI diagnostics, thereby potentially reducing delays in diagnosis and treatment initiation.

Conclusion

In conclusion, native CT imaging may serve as a valuable adjunct in the early diagnosis of spondylodiscitis, especially in settings where MRI is unavailable or contraindicated. A reduction of HU values in the intervertebral disc by approximately 25% and/or an increase of HU values in the vertebral body by approximately 30% compared to adjacent levels may suggest spondylodiscitis. These findings are independent of the spinal region or extent of bone destruction. We recommend prospective studies to validate these HU thresholds, evaluate diagnostic accuracy, and directly compare HU changes in spondylodiscitis versus degenerative diseases. Integrating CT-based HU analysis with clinical and laboratory data may expedite diagnosis and optimize patient care.

Abbreviations

MRI	Magnetic Resonance Imaging
CT	Computer tomography
PET/CT	Positron Emission Tomography
SEM	Standard error of mean
HU	Hounsfield Units
SD	Standard deviation
STIR	Short-Tau-Inversion-Recovery

VB Vertebral Body

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Authors' contributions

MP: Conception and design, administrative support, Collection and assembly of data, Provision of study materials or patients, Data analysis and interpretation, Manuscript writing, Final approval of manuscript. RT: Administrative support, Collection and assembly of data, Provision of study materials or patients, Data analysis and interpretation, Manuscript writing, Final approval of manuscript. CBM: Administrative support, Collection and assembly of data, Data analysis and interpretation, final approval of manuscript. DL: Administrative support, Collection and assembly of data, Data analysis and interpretation, final approval of manuscript. MER: Administrative support, Collection and assembly of data, Data analysis and interpretation, final approval of manuscript. CPB: Administrative support, Collection and assembly of data, Data analysis and interpretation, final approval of manuscript. JW: Administrative support, Provision of study materials or patients, Manuscript writing, Final approval of manuscript. MJS: Conception and design, administrative support, Collection and assembly of data, Provision of study materials or patients, Data analysis and interpretation, Manuscript writing, Final approval of manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Due to the retrospective nature of the study, the need for informed consent was waived by the local ethics committee of the Medical Faculty and University Hospital Düsseldorf (Register number 2020 – 914_1). This study was approved by the local ethics committee and was conducted according to the revised declaration of Helsinki.

Consent for publication

Not applicable because of the retrospective design of the investigation.

Competing interests

The authors declare no competing interests.

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References

- Martins R-P, Baruteau A-E, Treguer F, et al. [Magnetic resonance imaging in patients with pacemakers and implantable cardioverter-defibrillators: a systematic review]. *Ann Cardiol Angeiol (Paris)*. 2010;59:221–8.
- Alvarez IN, Madl J, Becker L et al. Patients' experience to mri examinations-a systematic qualitative review with meta-synthesis. *J Magn Reson Imaging JMRI*. <https://doi.org/10.1002/jmri.29365>. Epub ahead of print 27 March 2024.
- Malakhanov V, Seliverstov P, Lubashev Ya, et al. Computed tomography imaging of degenerative disease in the lumbar spine. *Int J Biomed*. 2019;9:182–4.
- Panda A, Das C, Baruah U. Imaging of vertebral fractures. *Indian J Endocrinol Metab*. 2014;18:295.
- Jean M, Irissou J-O, Gras G, et al. Diagnostic delay of pyogenic vertebral osteomyelitis and its associated factors. *Scand J Rheumatol*. 2017;46:64–8.
- Herren C, Jung N, Pishnamaz M et al. Spondylodiscitis: diagnosis and treatment options. *Dtsch Arztebl Int*. <https://doi.org/10.3238/arztebl.2017.0875>. Epub ahead of print 25 December 2017.
- Maamari J, Grach SL, Passerini M, et al. The use of MRI, PET/CT, and nuclear scintigraphy in the imaging of pyogenic native vertebral osteomyelitis: a systematic review and meta-analysis. *Spine J*. 2023;23:868–76.
- Lazzeri E, Bozzao A, Cataldo MA, et al. Joint EANM/ESNR and ESCMID-endorsed consensus document for the diagnosis of spine infection (spondylodiscitis) in adults. *Eur J Nucl Med Mol Imaging*. 2019;46:2464–87.
- Grane P, Josephsson A, Seferlis A, et al. Septic and aseptic post-operative discitis in the lumbar spine—evaluation by MR imaging. *Acta Radiol Stockh Swed* 1987. 1998;39:108–15.
- Kawakyu-O'Connor D, Bordia R, Nicola R. Magnetic resonance imaging of spinal emergencies. *Magn Reson Imaging Clin N Am*. 2016;24:325–44.
- Tins BJ, Cassar-Pullicino VN, Lalam RK. Magnetic resonance imaging of spinal infection. *Top Magn Reson Imaging TMRI*. 2007;18:213–22.
- Danchaivijitr N, Temram S, Thepmongkhon K, et al. Diagnostic accuracy of MR imaging in tuberculous spondylitis. *J Med Assoc Thai Chotmaihet Thangphaet*. 2007;90:1581–9.
- Shraim BA, Shraim MA, Ibrahim AR, et al. The association between early MRI and length of disability in acute lower back pain: a systematic review and narrative synthesis. *BMC Musculoskelet Disord*. 2021;22:983.
- Cannavale A, Santoni M, Nardis P, et al. Role of CT and MR imaging in the assessment of suspected spondylodiscitis and planning of needle biopsy. *Radiol Med (Torino)*. 2022;127:1023–31.
- von der Herren C. Höh N, Im Namen der leitlinienkommission der Deutschen wirbelsäulengesellschaft. Zusammenfassung der S2K-Leitlinie, diagnostik und therapie der spondylodisizitis (Stand 08/2020). *Wirbels*. 2021;5:18–20.
- Flückiger M, Andreisek G, Hasse B. CME: Akute Spondylodisizitis Praxis. 2014;103:1103–13.
- Chin TY, Peh WC. Imaging update on musculoskeletal infections. *J Clin Orthop Trauma*. 2021;22:101600.
- Marques ML, da Silva NP, van der Heijde D, et al. Hounsfield units measured in low dose CT reliably assess vertebral trabecular bone density changes over two years in axial spondyloarthritis. *Semin Arthritis Rheum*. 2023;58:152144.
- Ahern DP, McDonnell JM, Riffault M, et al. A meta-analysis of the diagnostic accuracy of Hounsfield units on computed topography relative to dual-energy X-ray absorptiometry for the diagnosis of osteoporosis in the spine surgery population. *Spine J*. 2021;21:1738–49.
- Schreiber JJ, Anderson PA, Rosas HG, et al. Hounsfield units for assessing bone mineral density and strength: A tool for osteoporosis management. *J Bone Jt Surg*. 2011;93:1057–63.
- Zhu J, Wu H, Chen Y, et al. The correlation between the change of Hounsfield units value and modic changes in the lumbar vertebral endplate. *BMC Musculoskelet Disord*. 2021;22:509.
- Levine ZH, Peskin AP, Holmgren AD, et al. Preliminary X-ray CT investigation to link Hounsfield unit measurements with the international system of units (SI). *PLoS ONE*. 2018;13:e0208820.
- Hurrell MA, Butler APH, Cook NJ, et al. Spectral Hounsfield units: a new radiological concept. *Eur Radiol*. 2012;22:1008–13.
- Patrick S, Birur NP, Gurushanth K, et al. Comparison of Gray values of cone-beam computed tomography with Hounsfield units of multislice computed tomography: an in vitro study. *Indian J Dent Res Off Publ Indian Soc Dent Res*. 2017;28:66–70.
- Stein G, Eysel P, Scheyerer M, Hrsg. Expertise Orthopädie und Unfallchirurgie Wirbelsäule.1. Auflage. Stuttgart: Thieme; 2019. <https://doi.org/10.1055/b-006-149533>.
- Raghavan M, Lazzeri E, Palestro CJ. Imaging of spondylodiscitis. *Semin Nucl Med*. 2018;48:131–47.
- Liang X, Liu Q, Xu J, et al. Hounsfield unit for assessing bone mineral density distribution within cervical vertebrae and its correlation with the intervertebral disc degeneration. *Front Endocrinol*. 2022;13:920167.
- Hendrickson NR, Pickhardt PJ, Del Rio AM, et al. Bone mineral density T-scores derived from CT Attenuation numbers (Hounsfield Units): Clinical Utility and Correlation with Dual-energy X-ray Absorptiometry. *Iowa Orthop J*. 2018;38:25–31.
- Armbrecht G, Felsenberg D, Ganswindt M, et al. Degenerative inter-vertebral disc disease osteochondrosis intervertebralis in europe: prevalence, geographic variation and radiological correlates in men and women aged 50 and over. *Rheumatology*. 2017;56:1189–99.
- Moore RJ. The vertebral endplate: disc degeneration, disc regeneration. *Eur Spine J*. 2006;15:333–7.
- Määtä JH, Kraatari M, Wolber L, et al. Vertebral endplate change as a feature of intervertebral disc degeneration: a heritability study. *Eur Spine J*. 2014;23:1856–62.
- Adams MA, Dolan P. Intervertebral disc degeneration: evidence for two distinct phenotypes. *J Anat*. 2012;221:497–506.

33. Mens MA, De Geus A, Wellenberg RHH, et al. Preliminary evaluation of dual-energy CT to quantitatively assess bone marrow edema in patients with diabetic foot ulcers and suspected osteomyelitis. *Eur Radiol.* 2023;33:5645–52.

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