Thieme

Bone Reporting and Data System (Bone-RADS) and Other Proposed Practice Guidelines for Reporting Bone Tumors

Bone Reporting and Data System (Bone-RADS) und andere vorgeschlagene Praxisleitlinien für die Meldung von Knochentumoren

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ABSTRACT

Background The purpose of this article is to review the different bone tumor radiology reporting systems [Bone Reporting and Data System (Bone-RADS), Osseous Tumor Reporting and Data System (OT-RADS), Solitary Bone Tumor Imaging Reporting and Data System (BTI-RADS), and Radiological Evaluation Score for Bone Tumors (REST)] and summarize their advantages and disadvantages.

Methods A selective search of PubMed was performed for literature regarding the definition and discussion of bone tumor reporting systems. No time frame was selected, but the search was particularly focused on current literature on musculoskeletal radiology lexicon.

Results To date, four major reporting systems has been proposed to standardize and systematize the reporting of imaging studies of bone tumors: Bone-RADS, OT-RADS, BTI-RADS, and REST. Both Bone-RADS and OT-RADS aid in the characterization and management of bone lesions on CT and MRI. OT-RADS and REST can be applied to MRI and radiography, respectively.

Conclusion Radiologists play a central role in the detection and characterization of asymptomatic (or incidentally detected) and symptomatic bone tumors. There are several existing bone tumor reporting systems with various advantages and disadvantages including emphasis on lesion characterization as well as management of incidentally detected bone lesions.

Key Points

1. Four bone tumor reporting systems have been proposed thus far.
2. Bone-RADS guides management of incidental bone lesions on CT and MRI.
3. OT-RADS guides management of bone lesions on MRI with high accuracy.
4. BTI-RADS classifies bone tumors on CT and MRI.

ZUSAMMENFASSUNG

Hintergrund Der Zweck dieses Artikels ist es, die verschiedenen Befundungssysteme für Knochentumorradiologie [Bone Reporting and Data System (Bone-RADS), Osseous Tumor Reporting and Data System (OT-RADS), Solitary Bone Tumor Imaging Reporting and Data System (BTI-RADS) und Radiological Evaluation Score for Bone Tumors (REST)] zu überprüfen und ihre Vor- und Nachteile zusammenzufassen.

Methode PubMed wurde selektiv nach Literatur zur Definition und Diskussion von Knochentumormeldesystemen durchsucht. Es wurde kein Zeitrahmen gewählt, aber die Suche konzentrierte sich insbesondere auf die aktuelle Literatur zum muskuloskelettalen Radiologielexikon.

Ergebnisse und Schlussfolgerung Bisher wurden vier große Berichtssysteme vorgeschlagen, um die Berichterstattung über bildgebende Untersuchungen von Knochentumoren zu standardisieren und zu systematisieren: Bone Reporting and Data System (Bone-RADS), Osseous Tumor Reporting and Data System (OT-RADS), Solitary Bone Tumor Imaging Reporting and Data System (BTI-RADS) und Radiological Evaluation Score for Bone Tumors (REST). Sowohl Bone-RADS als

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auch OT-RADS helfen bei der Charakterisierung und Behandlung von Knochenläsionen im CT und MRT. OT-RADS und REST können auf MRT bzw. Röntgen angewendet werden.

Kernaussagen

Radiologen spielen eine zentrale Rolle bei der Erkennung und Charakterisierung von asymptomatischen (oder zufällig entdeckten) und symptomatischen Knochentumoren. Es gibt mehrere bestehende Systeme zur Befundung von Knochentumoren mit verschiedenen Vor- und Nachteilen, einschließlich des Schwerpunkts auf der Charakterisierung von Läsionen sowie der Behandlung von zufällig entdeckten Knochenläsionen.

Zitierweise

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Introduction

Accounting for 0.2 % of all diagnosed neoplasms in the US [1], primary bone tumors are rare with variable histology and biologic aggressivity. In 2020, the World Health Organization (WHO) published an updated classification for bone tumors which included chondrogenic tumors, osteogenic tumors, fibrogenic tumors, vascular tumors, osteoclastic giant cell-rich tumors, notochordal tumors, other mesenchymal tumors of bone, hematopoietic neoplasms of bone, and undifferentiated small round cell sarcomas of bone and soft tissue [2]. Of these, osteosarcoma (28–37 %) and chondrogenic sarcomas (23.6–30 %) are the most frequent primary bone sarcomas [3, 4]. Management of these tumors can be challenging due to their rarity and heterogeneity and requires a multi-disciplinary approach. Radiologists play a central role in the detection and characterization of asymptomatic (or incidentally detected) and symptomatic bone tumors. Accurate radiology reports can initiate appropriate management pathways with some lesions requiring no further workup based on their determinate imaging appearance (typical non-ossifying fibroma) while other lesions require surveillance and/or biopsy.

A current literature review of the musculoskeletal bone tumor radiology lexicon reveals four major reporting systems (▶ **Table 1**) with the goal of standardized and systematic reporting of the imaging studies of bone tumors: Bone Reporting and Data System (Bone-RADS) [5], Osseous Tumor Reporting and Data System (OT-RADS) [6], Solitary Bone Tumor Imaging Reporting and Data System (BTI-RADS) [7], and Radiological Evaluation Score for Bone Tumors (REST) [8]. The purpose of this article is to review the different bone tumor reporting systems and summarize their advantages and disadvantages.

Bone Reporting and Data System (Bone-RADS)

In 2021, the Practice Guidelines and Technical Standards Committee of the Society of Skeletal Radiology proposed a reporting system for incidental solitary bone lesions found on computed tomography (CT) or magnetic resonance imaging (MRI) scans for adult patients: bone reporting and data system (Bone-RADS) [5]. Their committee was comprised of 12 musculoskeletal radiologists and an oncologic surgeon. This reporting system does not apply to multiple bone tumors or tumors in children. According to Bone-RADS, an incidentally detected bone lesion can be categorized into 4 groups: Bone-RADS1 (no further management); Bone-RADS2, (perform additional imaging); Bone-RADS3 (perform follow-up imaging); and Bone-RADS4, (biopsy and/or oncologic referral) [5]. To classify a lesion, management algorithms for incidentally detected lesions on CT scan and MRI are proposed in the bone-RADS system.

The CT algorithms necessitate the differentiation of the lesion as either lucent or sclerotic/mixed. Lucency was defined quantitatively as having lower attenuation in Hounsfield units (HU) than the normal trabecular bone (up to 200 HU) in at least 90 % of the lesion [5, 9]. Lucent lesions can include cystic or solid non-sclerotic areas, such as giant cell tumors or aneurysmal bone cysts. Sclerotic lesions (▶ **Fig. 1**), on the other hand, were defined as showing ≥ 50 % attenuation greater than adjacent trabecular bone, while those lesions that did not meet this threshold were considered mixed density lesions. Mixed lesions contain an equal (1:1 ratio) combination of osteoblastic and osteolytic areas that are determined relative to adjacent trabecular bone [5]. For simplicity, sclerotic and mixed bone tumors are treated using the same algorithm. Subsequently, the algorithms for lucent and sclerotic/mixed lesions assess a combination of clinical (pain attributable to the lesion, history of malignancy) and radiological features (cortical involvement, soft tissue expansion, pathologic fracture, and aggressive periosteal reaction) to determine Bone-RADs category.

The MRI management algorithm is based on the intensity of the lesion on T1-weighted images. For bone tumors detected on an algorithm without T1-weighted images, further imaging is requested. For MRI-based Bone-RADS, bone lesions are broadly characterized as having high T1 or low T1 content [5]. For T1 hyperintense or bright lesions, the algorithm then evaluates signal characteristics relative to adjacent macroscopic fat or skeletal muscle. T1 lesions that are minimally bright relative to skeletal muscle are further evaluated based on their in- and out-phase chemical shift attributes denoting the presence of intralesional microscopic fat, a marker for non-marrow replacement (▶ **Fig. 2**). Bone-RADS recommends the use of a T1 hypointense bone lesion algorithm for lesions with internal hemorrhage. For T1 hypointense or dark lesions, T2-signal properties are next evaluated using fat-saturated T2-weighted images or short-tau inverted recovery (STIR) sequences. T2 hypointensity was described as having little to no free water like T2 signal of air, cortical bone, skeletal muscle, or sufficiently fat-suppressed fatty tissue. T2 hyperintensity was defined as showing very high T2 sig-

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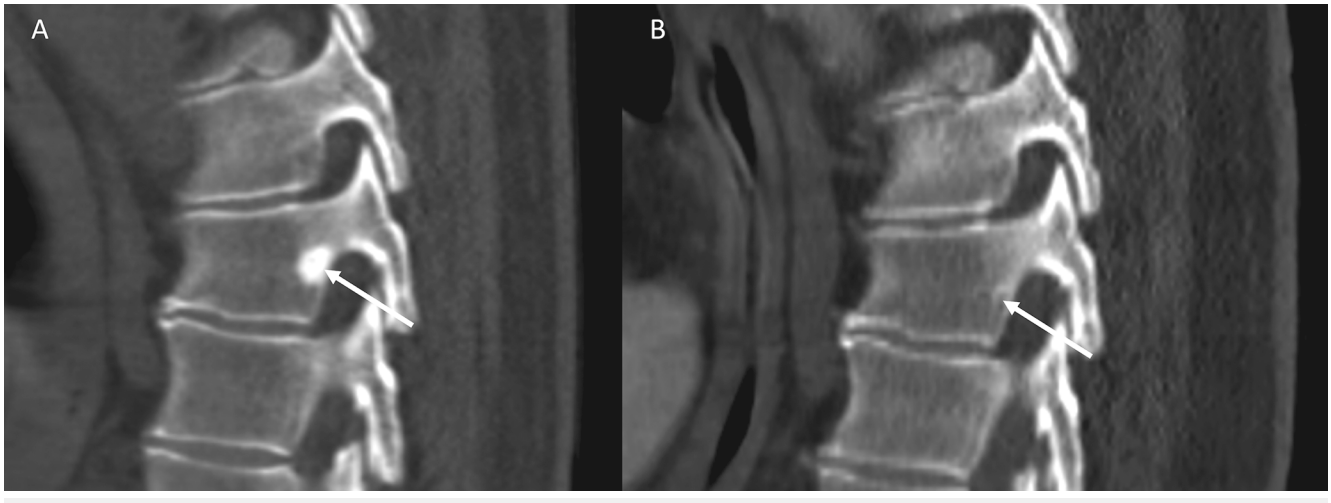
▶ **Table 1** Summary of Existing Reporting and Data Systems for Bone Tumors and Lesions.

	Bone Reporting and Data System (Bone-RADS)	Osseous Tumor Reporting and Data System (OT-RADS)	Solitary Bone Tumor Imaging Reporting and Data System (BTI-RADS)	Radiological Evaluation Score for Bone Tumors (REST)
Center	**Multiple**	**Single**	**Single**	**Single**
Subspecialties	▪ Radiology ▪ Orthopedic oncology	▪ Radiology ▪ Orthopedic oncology	▪ Radiology	▪ Orthopedic oncology ▪ Surgical oncology
Scope	Incidentally detected solitary bone tumors in adults	Osseous lesions > 1 cm in age 14–100 years	Solitary bone tumors in predominantly adults (mean age 40.7 +/– 18.3)	Primary bone tumor
Modality	CT and MRI	MRI	CT and MRI	Radiography
Classification scheme	▪ Bone-RADS I: definitely benign ▪ Bone-RADS II: more imaging is required ▪ Bone-RADS III: indeterminate ▪ Bone-RADS IV: suspicious for malignancy or requires orthopedic oncology follow-up (at risk for pathological fracture)	▪ OT-RADS I: negative ▪ OT-RADS II: definitely benign ▪ OT-RADS III: probably benign ▪ OT-RADS IV: suspicious for malignancy or indeterminate ▪ OT-RADS V: highly suggestive of malignancy ▪ OT-RADS VI: known biopsy-proven malignancy or recurrent malignancy	▪ BTI-RADS I: benign ▪ BTI-RADS II: likely benign ▪ BTI-RADS III: suspicion for malignancy ▪ BTI-RADS IV: likely malignant	▪ Suspected benign tumor (REST final score< 3) ▪ Suspected malignant tumor (REST final score≥3)
Methodology	Expert panel or consensus guidelines	4 MSK radiologists retrospectively evaluated 136 osseous tumors (77 benign, 59 malignant) with histology or minimum 2-year follow-up with high diagnostic accuracy (AUC: 0.92 (0.87, 0.96) and inter-reader agreement (ICC 2-way agreement: 0.78 (0.73, 0.83).	2 MSK radiologists and 1 general radiologist retrospectively evaluated 230 solitary bone tumors (230 histologically confirmed; 155 benign and 75 malignant) with fair inter-reader agreement (kappa – 0.67)	2 orthopedic oncologists and 2 surgical oncologists retrospectively evaluated 100 histologically confirmed primary bone tumors with high diagnostic accuracy (AUC: 0.92 (0.87, 0.96) and inter-reader agreement (ICC 2-way agreement: 0.97 (p value< 0.05).



▶ **Fig. 1** 70-year-old man with a history of pancreatitis presents with incidental T8 posterior vertebral sclerotic lesion without extension to the pedicle. **A** Sagittal CT of the abdomen and pelvis shows a sclerotic lesion (arrow) with mean attenuation of 887 HU and range of 619–1036. **B** A remote chest CT scan (sagittal image) performed 3 years ago did not show a lesion in the posterior T8 vertebral body. As such, a biopsy was performed and this was confirmed to be a prostate cancer metastasis.

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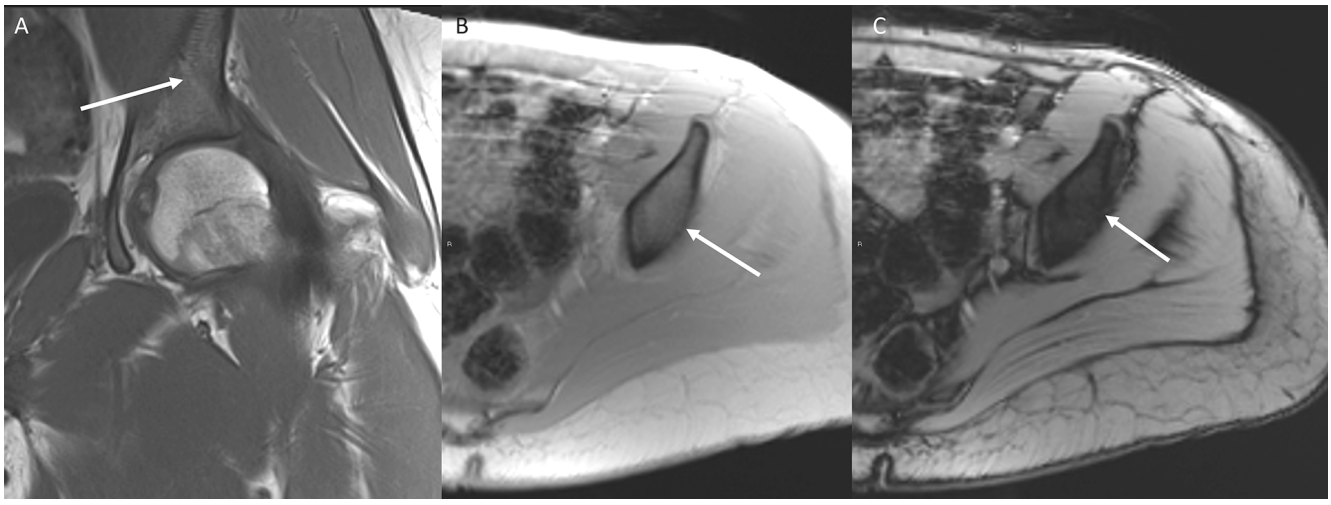
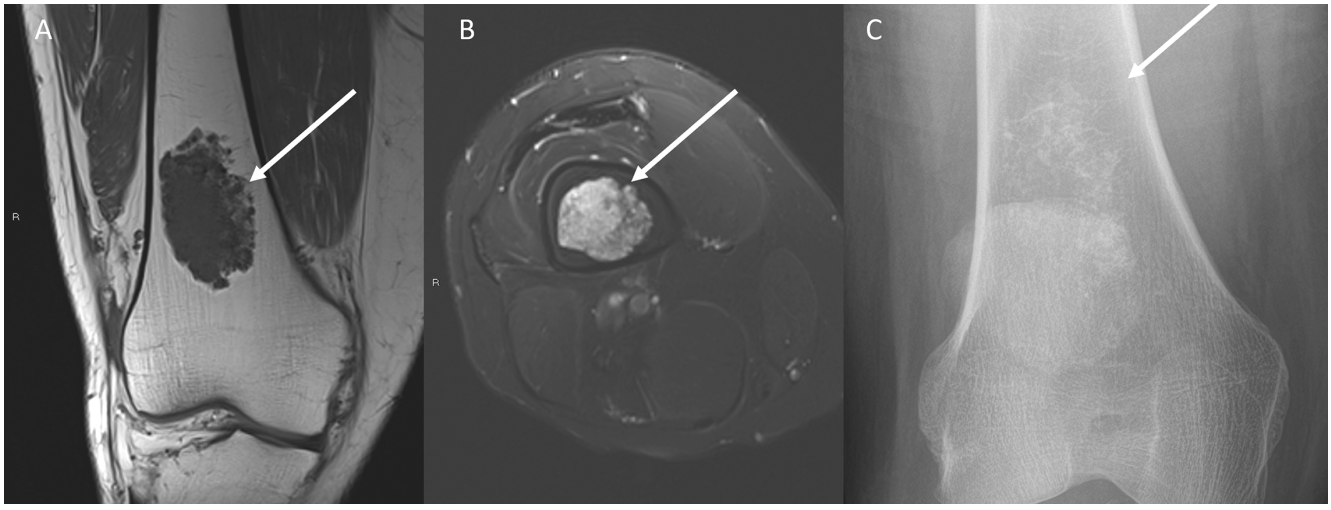


▶ **Fig. 2** Incidentally detected, asymptomatic T1 signal abnormality that is minimally higher than adjacent gluteal muscles in the left acetabulum (arrow on **A**) that exhibits qualitative and quantitative signal drop out on axial in-phase (**B**) and opposed-phase chemical shift imaging through the region of interest (High T1 Solitary Bone Lesion Algorithm for Bone-RADS), compatible with hematopoietic marrow in this 15-year-old patient (Bone-RADS I or OT-RADS I). Such a signal abnormality cannot be analyzed using BTI-RADS which is based on solitary bone tumors and does not allow for triaging using chemical shift imaging.



▶ **Fig. 3** Incidentally detected asymptomatic skeletal lesion on MRI of the right lower extremity. The lesion is hypointense to skeletal muscle on coronal T1-weighted image (**A**) and hyperintense in an axial fluid-sensitive sequence (**B**) through the right lower extremity. The lesion has characteristic imaging features of an enchondroma. It would be characterized as a benign lesion (Bone-RADS I, OT-RADS II and BTI-RADS I). Correlation with radiographs (**C**) shows chondroid matrix without any other aggressive features, suspected benign tumor (REST final score < 3).

nals comparable to fluid (cerebrospinal fluid, bladder) (▶ **Fig. 3**). The flowcharts then incorporate clinical data and imaging features to designate a Bone-RADS classification.

The advantages of Bone-RADS include its comprehensive and thorough approach to incidentally detected lesions on CT or MRI with illustrative case scenarios and a flowchart for clinical application. The algorithms are conservative, and the goal is not to miss a potentially aggressive lesion, including clinical characteristics to guide management (▶ **Fig. 4**). The system is designed by consensus among musculoskeletal radiologists from multiple institutions and one orthopedic oncologist with experience with bone tumors. Unlike the other bone tumor lexicon systems, Bone-RADS considers a benign lesion to be at risk for pathological fracture requiring orthopedic oncology consultation. The disadvantages include the lack of data supporting its accuracy and no clinical outcomes or cost-effectiveness data. Lastly, no musculoskeletal pathologist was included in its conception, which is probably appropriate as the system is designed for the management of incidental bone lesions often detected by general radiologists in routine clinical practice.

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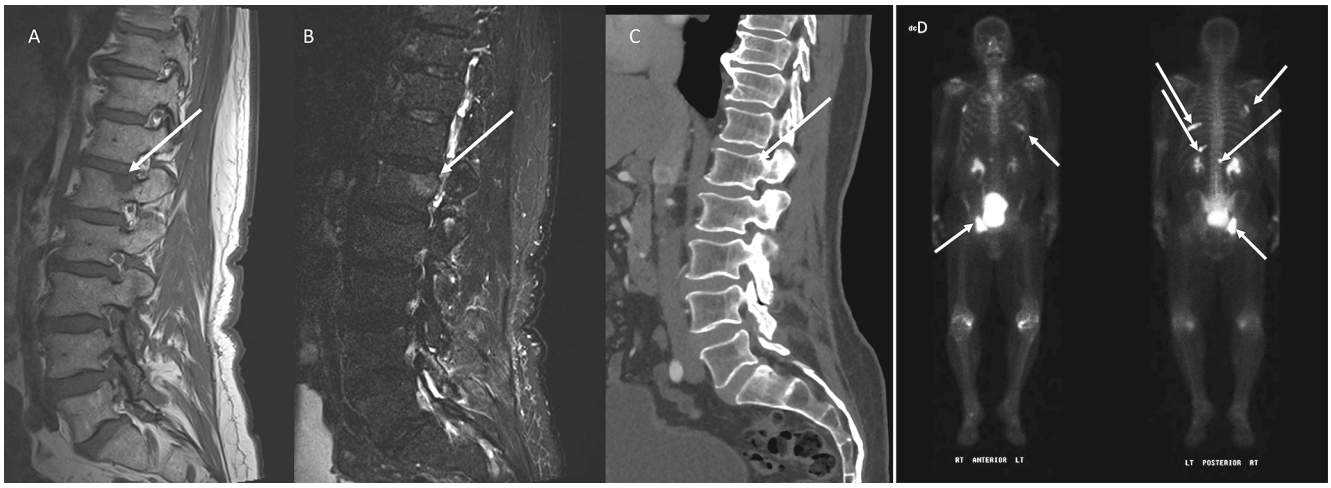


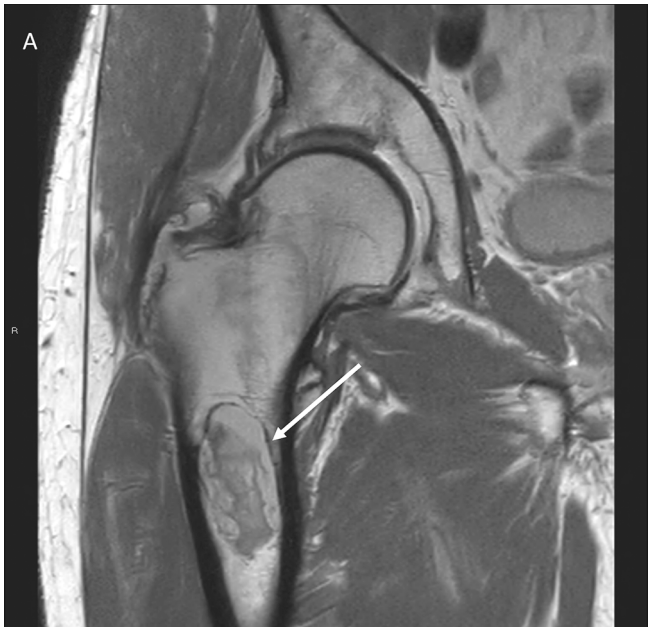
▶ **Fig. 4** 81-year-old man without known history of malignancy presented with an incidentally detected, asymptomatic T1-hypointense bone lesion (**A**) in the posterior superior aspect of the L1 vertebral body (arrow). The lesion (arrow) was heterogeneously hyperintense on sagittal STIR sequence (**B**). Sagittal CT (**C**) image showed no CT correlate in the area of concern (arrow). Due to the absence of typical imaging characteristics of a benign lesion such as geode, enchondroma, non-ossifying fibroma, or fibrous dysplasia, the lesion was categorized as Bone-RADS II and additional imaging was requested. A subsequent bone scan (**D**) showed multiple sites (arrows) of radiotracer avidity compatible with metastatic disease.

Osseous Tumor Reporting and Data System (OT-RADS)

Inspired by the successful Breast Imaging and Reporting System (BI-RADS), 5 experienced musculoskeletal radiologists proposed a reporting system for osseus tumors [6]. Similar to BI-RADS, this reporting system also has 7 categories (OT-RADS 0 to OT-RADS VI). The authors of this system prioritized quantitative over qualitative categorization and, similar to BI-RADS, incorporated a percentage into their classification denoting the likelihood of malignancy. An MRI study that included proper visualization of the tumor on at least one plane in each of the T1-weighted, fluid sensitive (fat-suppressed T2-weighted or STIR), and fluid-sensitive T1-weighted sequences was deemed a complete MRI study. Also, the authors suggested using apparent diffusion coefficient (ADC) values and diffusion-weighted imaging (DWI) sequences as a complementary source if obtained.

OT-RADS 0 designation is used in the context of incomplete imaging or unavailable prior imaging, similar to BI-RADS 0 (▶ **Fig. 5**). OT-RADS I can be used when no further follow-up is needed. OT-RADS II includes the lesions that are "definitely benign" with essentially 0 % likelihood of malignancy. "Probably benign" lesions are classified as OT-RADS III with ≤ 2 % likelihood of malignancy. Lesions that are suspicious for malignancy or indeterminate lesions are classified as OT-RADS IV with less than 50 % chance of malignancy. OT-RADS V encompasses the lesions that are highly suggestive of malignancy (≥ 50 % likelihood of malignancy) (▶ **Fig. 6**). Lastly, OT-RADS VI was used to classify the previously known or recurrence of malignant lesions. This scheme most closely mimics the well-established BI-RADS system.

The authors of OT-RADS used typical examples of each category to elaborate their classifications and defined rough thresholds for tumor size and hyperintensity. Also, they used structural details such as the depth of endosteal scalloping of the lesion to further distinguish between the classifications. They presented a series of common bone tumors and briefly described their patient demographics, anatomical location, T1- and T2-weighted features, margins, marrow, edema, periosteal reaction, and adjoining soft tissues as well as their respective OT-RADS classification. To test the reliability of their proposed system, OT-RADS authors conducted a blinded observational study with 4 experienced musculoskeletal radiologists who familiarized themselves with the OT-RADS beforehand. They used the biopsies, surgical pathology reports, or a minimum of a 2-year follow-up period for benign le-



▶ **Fig. 5** 75-year-old man with hip pain and an incidentally detected right proximal sub-trochanteric skeletal lesion on intermediate weighted imaging. No T1-weighted imaging was available. This lesion would be characterized as Bone-RADS II or OT-RADS 0.

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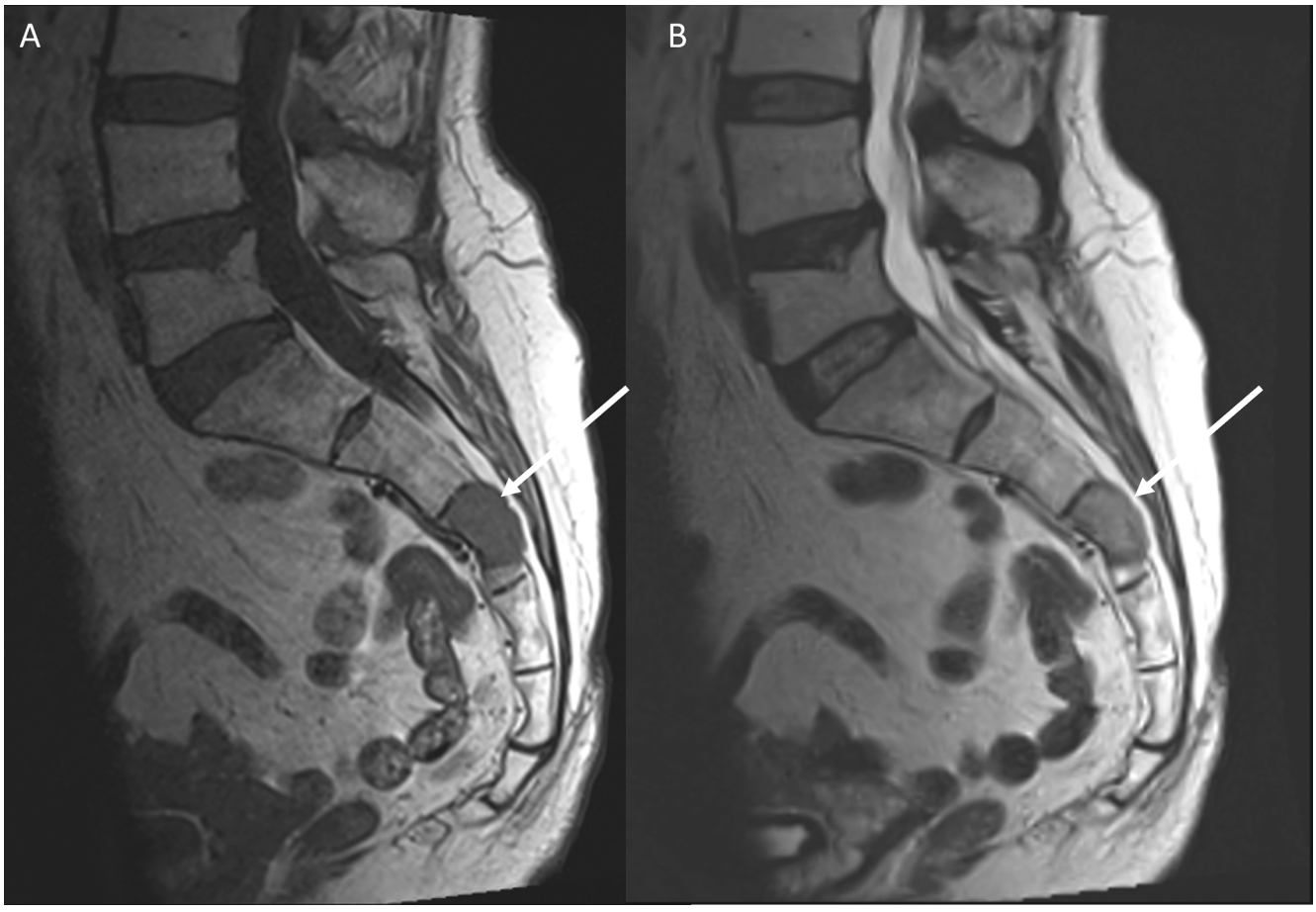

▶ **Fig. 6** Incidentally detected bone lesion in the S3 vertebral body (arrow) on sagittal T1- (**A**) and T2-weighted (**B**) sequences with extra-osseous extension into the sacral spinal canal (low T1 solitary bone lesion algorithm on MRI with concordant high T2 signal and aggressive imaging features) compatible with Bone-RADS IV, OT-RADS V or BTI-RADS IV.

sions as their reference standard. Compared with individual tumor signal characteristics, a dichotomized OT-RADS (OT-RADS I–III as benign and OT-RADS IV–VI as malignant) provided superior performance and showed excellent reliability (area under the curve = 0.92–0.97 and inter-reader agreement = 0.78) and diagnostic accuracy for characterizing benign and malignant bone tumors with high sensitivity (93–100 %) and moderate specificity (71–86 %). The authors also conducted a similar study to assess the added diagnostic value of incorporating the DWI sequences into the OT-RADS. They concluded that the addition of DWI does not significantly enhance the diagnostic performance of OT-RADS [10].

The fact that two studies were conducted to test its efficacy is a major advantage for OT-RADS. Also, the brevity of the classifications, similar to the previously established BI-RADS, and the inclusion of radiographic findings in the protocol makes OT-RADS both comprehensive and easy to apply. The disadvantages of OT-RADS include the lack of guidelines regarding bone tumors detected on CT scans. In addition, OT-RADS relies on preexisting knowledge of the typical appearance of classic bone tumors to classify each of those lesions in one of the categories. This approach might not be applicable to every bone tumor and may be challenging for general radiologists lacking a priori familiarity with bone tumors.

Solitary Bone Tumor Imaging Reporting and Data System (BTI-RADS)

Proposed in 2021, the Solitary Bone Tumor Imaging Reporting and Data System (BTI-RADS) is a reporting system that defines the imaging features associated with aggressive and non-aggressive solitary bone lesions. Similar to Bone-RADS, BTI-RADS incorporates CT and MR imaging features as well as clinical data. Having 3 experienced radiologists as their readers, the authors conducted a blinded, cross-sectional retrospective investigation of 230 solitary bone lesions and compared the results with the previously established histopathological diagnosis (global study sample). According to the reports of one reader, the frequency of each benign or malignant lesion was used to define 7 benign and 9 malignant (6 minor and 3 major) indicators. Based on the number of positive indicators, the authors proposed a 4-category reporting system: BTI-RADS I: benign; BTI-RADS II: likely benign; BTI-RADS III: suspicious for malignancy; and BTI-RADS IV: likely malignant. BTI-RADS I was defined as a lesion with features of a typical “do not touch” lesion which has ≥ 2 benign indicators “and” ≤ 1 minor malignant indicator. The authors defined BTI-RADS II as a lesion without the imaging features of a typical “do not touch” lesion which has ≥ 2 benign indicators “and” ≤ 1 minor

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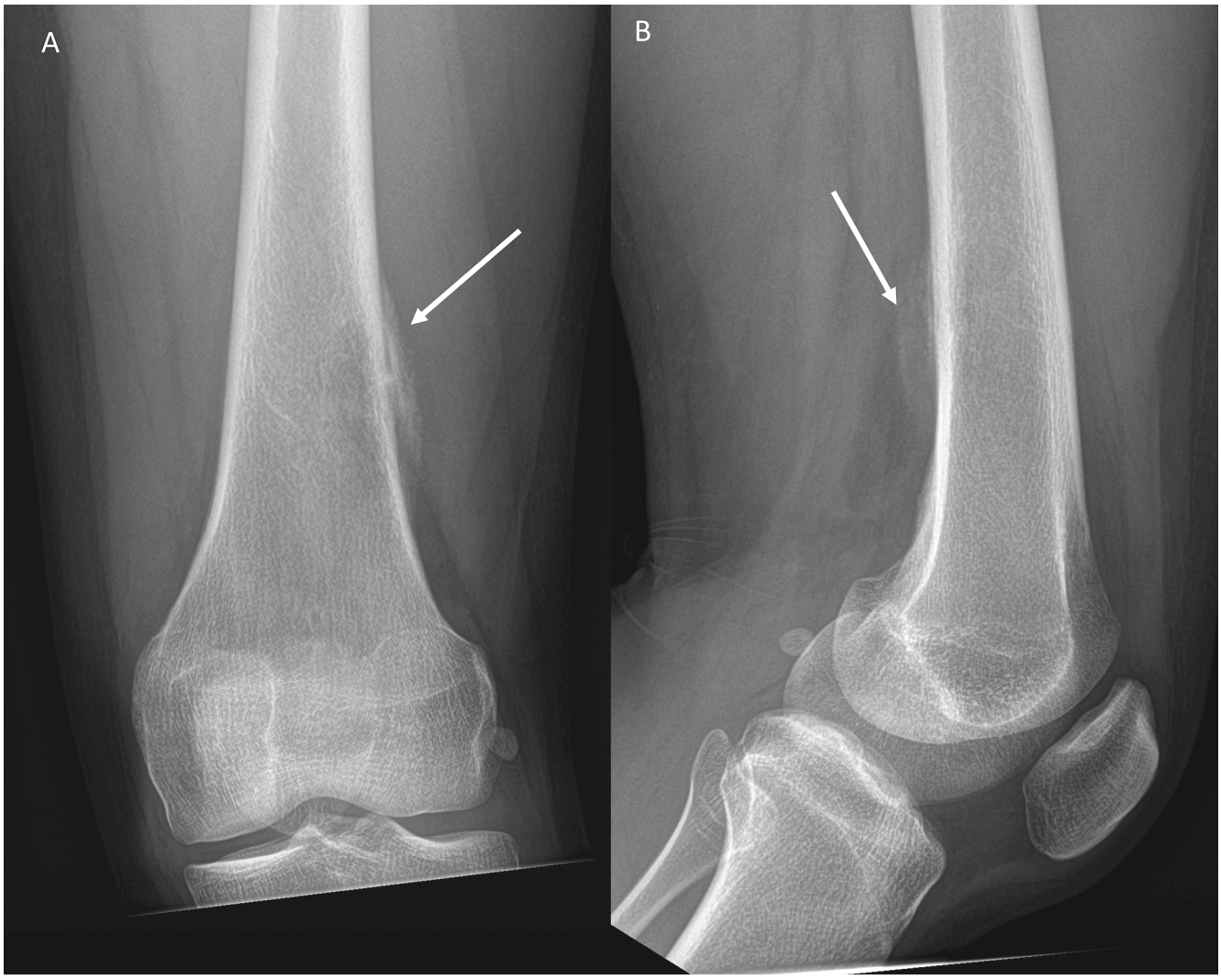

▶ **Fig. 7** 15-year-old female with left distal thigh pain. AP (**A**) and lateral (**B**) radiographs of the left distal femur show an aggressive lucent distal diaphyseal skeletal lesion with cortical breach, ill-defined borders, and aggressive periosteal reaction. This would be classified as an aggressive lesion by REST and ultimately diagnosed as conventional osteosarcoma (FNCLCC grade 3 of 3). The other three reporting systems (Bone-RADS, OT-RADS and BTI-RADS) do not apply as their scope encompasses cross-sectional imaging alone.

malignant indicator. BTI-RADS III was classified as a lesion with ≤ 1 benign indicator "or" < 3 minor malignant indicators. Eventually, BTI-RADS IV was described as a lesion with ≥ 3 minor malignant indicators or any major malignant indicator.

In their study sample, the frequency of benign and malignant lesions was 67 % and 33 %, respectively. The authors then posited that a valid benign indicator should be associated with at least 87 % (67 % + 20 %) of the benign lesions, and valid minor and major malignant indicators should be associated with at least 53 % (33 + 20 %) and 73 % (33 + 40 %) of the malignant lesions, respectively. After the analysis of all 3 readers' reports, the authors found a modified Lodwick-Madewell grade III, an aggressive periosteal reaction, and suspected metastatic disease as major malignant indicators. Notably, all 3 major malignant indicators were from CT scan findings signifying the role of the CT scan in BTI-RADS. Overall, they found 6 indicators among CT findings, 7 indicators among MRI findings, and 3 general indicators (pelvic location, extremity location, and age > = 50 years) with fair to excellent agreement between the readers for almost all indicators. The authors describe indeterminate features comprised of lesion characteristics that vary among the benign or malignant lesions with a frequency of less than 20 %.

Conducting a study to test their proposed system is a strength of BTI-RADS. Arranging the indicators into 3 levels of benign, minor malignant, and major malignant can make it easier for radiologists and clinicians to apply the system in their routine practice. Despite their valuable efforts conducting a validation study, the BTI-RADs is founded on histologically confirmed bone tumors and may misclassify clinically challenging bone lesions, i. e., the management of an incidentally detected solitary sclerotic lesion mimicking an enostosis (a "do not touch" type of lesion) in a patient with prostate cancer. Also, BTI-RADS does not account for scenarios where only one modality or incomplete imaging is available. The prevalence of malignant tumors in their study popula-

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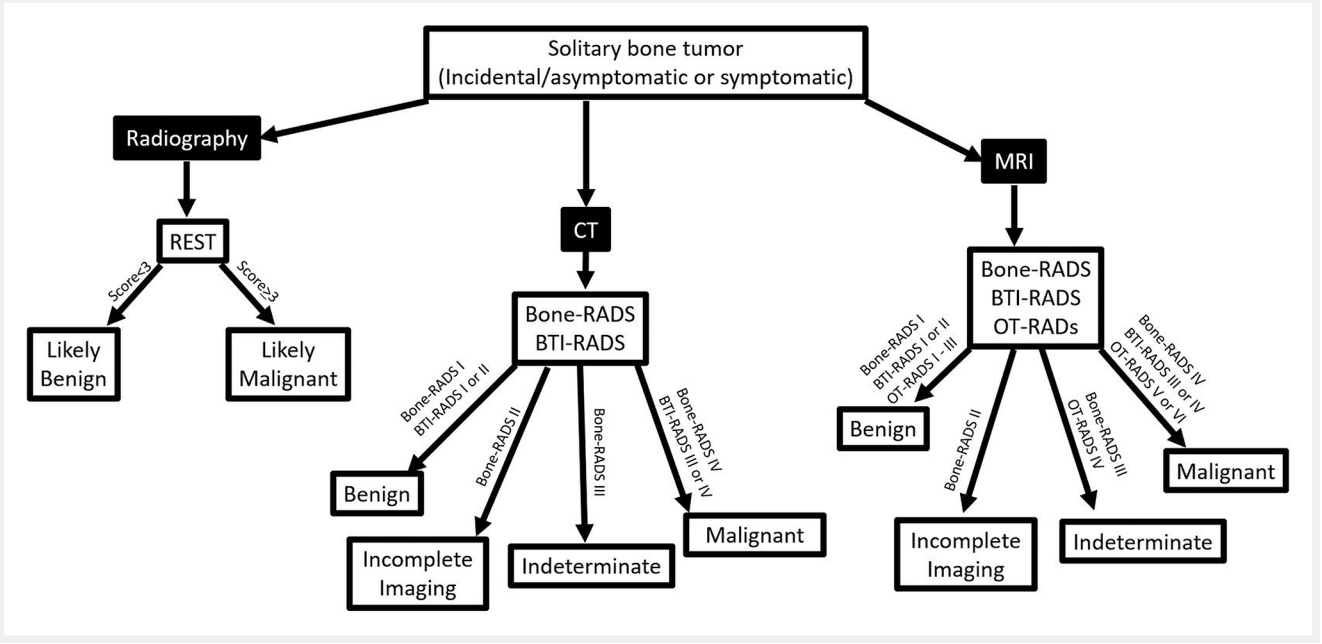
tion was over-represented when compared with the prevalence of such lesions in the general population. This selection bias may limit the application of the study results. Lastly, children and tumors in ribs as well as the cranium were excluded.

Radiological Evaluation Score for Bone Tumors (REST)

In 2021, a team of orthopedic surgeons and anesthesiologists investigated an assessment method for suspected bone tumors visualized on plain radiographs and proposed Radiological Evaluation Score for Bone Tumors (REST). Their primary goal was to establish an objective approach for the differentiation of benign from malignant lesions using the plain radiographs. The authors suggested 8 radiographic features for scoring the lesions: characterization (osteolytic versus mixed/osteoblastic) and contents (absent mineralization versus osteoid/chondroid matrix) of the tumor, cortical breach, distinctiveness (well-defined versus ill-defined borders), distribution (narrow versus wide transition zone), periosteal reaction (absent/benign type versus malignant type), soft tissue swelling, and presence or absence of a pathological fracture. Based on the presence or absence of each one of these features, they assigned a score of 1 or 0 to the lesion, respectively. REST score = < 3 represented a likely benign tumor, and a REST score > 3 was shown to be significantly associated with malignancy.

To investigate their proposal, the authors conducted a retrospective observational study and included 100 primary bone lesions which had antero-posterior and lateral view radiographs and confirmatory histopathological diagnosis (49 benign and 51 malignant). They considered 8 imaging features as their target features and tasked 4 readers (2 orthopedic and 2 surgical oncologists) with independently reviewing the radiographs, scoring each lesion based on the REST system, and reporting their subjective comments on whether the lesion was benign or malignant. The reviewers were blinded to the final diagnosis. They reported a mean REST score of 1.10 (95 % confidence interval (CI): 0.83–1.37) and 6.16 (95 % CI: 5.86–6.46) for benign and malignant lesions, respectively. When tested individually, just one of the imaging features (fracture) was not statistically correlated with the diagnosis of the lesion. The area under the curve (AUC) for the receiver operator characteristics (ROC) curve showed excellent diagnostic accuracy with the REST score of 3.5 being the most sensitive score (AUC = 0.99, sensitivity = 98 %). The readers had complete agreement in their REST scores (ICC = 0.985). They also found that as the REST score increases, so does the probability of the lesion being malignant (▶ **Fig. 7**).

The REST scoring system has shown its capabilities regarding the accurate diagnosis of benign versus malignant bone tumors in an observational study. As the readers of the study were all orthopedic or surgical oncologists reviewing the images from a clinical standpoint, this scoring system is readily usable for clinicians. However, no radiologists or pathologists were included in this classification scheme. Among the various reporting/scoring systems, the REST is the only one which is exclusively based on radiography, the backbone of bone tumor diagnosis. Adopting a binary scoring system and having a concise structure would also make the application of REST more convenient. However, exclusivity to plain radiographs and exclusion of other common imaging modalities are substantial limiting factors for this scoring system. The supporting foundation of this scoring system is built on a study



▶ **Fig. 8** A proposed guide for the application of reporting systems based on the available modality. Bone-RADS: Bone Reporting and Data System; BTI-RADS: Solitary Bone Tumor Imaging Reporting and Data System; OT-RADS: Osseous Tumor Reporting and Data System; REST: Radiological Evaluation Score for Bone Tumors.

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that was conducted on a skewed sample of radiographs: 49 % of the studied lesions were malignant and only histologically confirmed tumors, potentially limiting application to incidental bone lesions with non-aggressive features. Lastly, the REST score does not provide recommendations or guidelines on follow-up images or referral for orthopedic oncologist.

Future Directions

At this time, the four proposed bone tumor reporting systems are in their infancy and there is no data regarding their acceptance by multi-disciplinary teams/clinical colleagues or their use or application in routine clinical practice in Germany or other regions. Of note, orthopedic oncologists did participate in the development of REST, Bone-RADS and OT-RADS suggesting overall a clinical need for such algorithms. Until a unifying reporting system is introduced, it may be challenging to choose or implement a single system in routine clinical practice. ▶ **Fig. 8** represents a suggested flowchart as a decision guide for choosing the proper data system based on the availability of the imaging modalities. As the application of artificial intelligence (AI) in medicine is expanding, it is plausible to assume that AI will eventually play a decisive role in the development and optimization of reporting systems. Although there is published data on the use of quantitative MRI-based texture analysis for the grading of cartilaginous bone tumors as well as machine learning approaches for bone chondrosarcoma classification on radiography, CT, and MRI, these have not been included in routine clinical practice or in radiological reporting schemes as of yet [11–15]. Ideally, there will eventually be a unifying nomogram that combines both clinical and multi-parametric/modality radiology data to accurately and noninvasively characterize a bone lesion and guide patient management.

Conclusion

Despite the availability of several proposed reporting systems, prospective data regarding clinical outcomes and cost-effectiveness is lacking. As such, there is no consensus regarding the application of any of the existing bone-tumor reporting systems. An optimal unified reporting system should ideally be applicable in the pediatric as well as the adult setting, be optimized for clinical use by all stakeholders and clinical sub-specialties, and incorporate all modalities into a user-friendly yet comprehensive system that supports clinical management. More studies with larger datasets and multidisciplinary reviewer teams are mandatory for such a system.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Franchi A. Epidemiology and classification of bone tumors. Clin Cases Miner Bone Metab 2012; 9 (2): 92–95

[2] Ahlawat S, Fayad LM. Revisiting the WHO classification system of bone tumours: Emphasis on advanced magnetic resonance imaging sequences. part 2. Polish journal of radiology 2020; 85 (1): 409–419. doi:10.5114/pjr.2020.98686

[3] Hauben EI, Hogendoorn PCW. Chapter 1 – epidemiology of primary bone tumors and economical aspects of bone metastases. In: Heymann D, ed.; Bone cancer (second edition). San Diego: Academic Press; 2015: 5–10. doi:10.1016/B978-0-12-416721-6.00001-7. https://www.sciencedirect.com/science/article/pii/B9780124167216000017

[4] Stiller CA, Trama A, Serraino D et al. Descriptive epidemiology of sarcomas in europe: Report from the RARECARE project. European journal of cancer 2013; 49 (3): 684–695. doi:10.1016/j.ejca.2012.09.011

[5] Chang CY, Garner HW, Ahlawat S et al. Society of skeletal radiology-white paper. guidelines for the diagnostic management of incidental solitary bone lesions on CT and MRI in adults: Bone reporting and data system (bone-RADS). Skeletal Radiol 2022; 51 (9): 1743–1764. doi:10.1007/s00256-022-04022-8

[6] Chhabra A, Gupta A, Thakur U et al. Osseous tumor reporting and data System—Multireader validation study. J Comput Assist Tomogr 2021; 45 (4). doi:10.1097/RCT.0000000000001184. https://journals.lww.com/jcat/Fulltext/2021/07000/Osseous_Tumor_Reporting_and_Data.12.aspx

[7] Ribeiro GJ, Gillet R, Hossu G et al. Solitary bone tumor imaging reporting and data system (BTI-RADS): Initial assessment of a systematic imaging evaluation and comprehensive reporting method. Eur Radiol 2021; 31 (10): 7637–7652. doi:10.1007/s00330-021-07745-9

[8] Salunke AA, Nandy K, Puj K et al. A proposed "Radiological evaluation score for bone tumors" (REST): An objective system for assessment of a radiograph in patients with suspected bone tumor. MUSCULOSKELETAL SURGERY 2022; 106 (4): 371–382. doi:10.1007/s12306-021-00711-0

[9] Alawi M, Begum A, Harraz M et al. Dual-energy X-ray absorptiometry (DEXA) scan versus computed tomography for bone density assessment. Cureus 2021; 13 (2): e13261. doi:10.7759/cureus.13261

[10] Guirguis M, Gupta A, Thakur U et al. Osseous-tissue tumor reporting and data system with diffusion-weighted imaging of bone tumors-an inter-reader analysis and whether it adds incremental value on tumor grading over conventional magnetic resonance imaging. J Comput Assist Tomogr 2023; 47 (2): 255–263. doi:10.1097/RCT.0000000000001415

[11] Gitto S, Cuocolo R, Albano D et al. MRI radiomics-based machine-learning classification of bone chondrosarcoma. Eur J Radiol 2020; 128: 109043. doi:10.1016/j.ejrad.2020.109043

[12] Gitto S, Cuocolo R, Emili I et al. Effects of interobserver variability on 2D and 3D CT- and MRI-based texture feature reproducibility of cartilaginous bone tumors. J Digital Imaging 2021; 34 (4): 820–832. doi:10.1007/s10278-021-00498-3

[13] Cilengir AH, Evrimler S, Serel TA et al. The diagnostic value of magnetic resonance imaging-based texture analysis in differentiating enchondroma and chondrosarcoma. Skeletal Radiol 2023; 52 (5): 1039–1049. doi:10.1007/s00256-022-04242-y

[14] Pan J, Zhang K, Le H et al. Radiomics nomograms based on non-enhanced MRI and clinical risk factors for the differentiation of chondrosarcoma from enchondroma. J Magn Reson Imaging 2021; 54 (4): 1314–1323. doi:10.1002/jmri.27690

[15] Fritz B, Müller DA, Sutter R et al. Magnetic resonance imaging-based grading of cartilaginous bone tumors: Added value of quantitative texture analysis. Invest Radiol 2018; 53 (11): 663–672. doi:10.1097/RLI.0000000000000486

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