Interobserver Variability in the Differential Diagnosis of Benign Bone Tumors and Tumor-like Lesions

Interobserver-Variabilität in der Differentialdiagnose gutartiger Knochentumoren und tumorähnlicher Knochenläsionen

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Key words
- benign bone tumor
- tumor-like lesions
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Abstract

Purpose: The interobserver-variability of radiological diagnosis of benign bone tumors (BBT) and tumor-like lesions (TLL) was examined in order to identify difficult-to-diagnose entities, to examine the frequency of advanced diagnostics and to describe the number of interdisciplinary tumor center diagnoses (IDT) in comparison with diagnoses upon referral (ED) and radiologists´ diagnoses (RD).

Materials and Methods: We retrospectively reviewed 413 patients with 272 BBT and 141 TLL, classified either histologically or through interdisciplinary consultation. Discrepancies between groups were analyzed and rates of additional imaging and biopsy to establish diagnosis were assessed.

Results: In BBT the number of identical radiological diagnoses was 56 (ED) and 81 % (RD) compared to the IDT, while in the latter additional imaging were obtained in 30 % cases. In 21 % (12 % to establish diagnosis) BBT were biopsied, the ED matching the histology 40 %, the RD 60 % and the IDT 76 % of the time. For TLL diagnosed through radiology, ED and RD matched IDT 31 % and 61 % of the time, with additional imaging being obtained in 21 % of cases (IDT). In 36 % (27 % to establish diagnosis) biopsy was performed, with histological diagnosis matching the IDT, RD and ED in 51, 27 and 20 %. Diagnostic challenges were apparent in enchondromas, non-ossifying fibromas (NOF), solitary (SBC) and aneurysmal bone cysts (ABC). Ganglia can be misinterpreted as a tumor.

Conclusions: Establishing a definitive diagnosis for BBT and TLL can be challenging with the latter posing greater difficulties. An interdisciplinary approach involving radiologists, orthopedics and pathologists was found to improve diagnostic accuracy.

Key Points:
- Benign bone tumors (BBT) and tumor-like lesions (TLL) present a diagnostic challenge, while enchondroma, NOF, SBC and ABC were difficult to diagnose, and ganglia can be misinterpreted as a tumor
- Additional imaging studies were required for diagnosis in 29 % and 21 % of cases for BBT and TLL, respectively, biopsies in 12 % of cases for BBT and 27 % for TLL
- Sound diagnoses can be made through interdisciplinary case discussion, while reducing the risk of overtreatment

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Zusammenfassung

Ziel: Die Interobservervariabilität der bildmorphologischen Diagnostik benigner Knochentumoren (BKT) und tumorähnlicher Läsionen (tumor-like lesion, TLL) wurde mit dem Ziel analysiert, schwierig beurteilbare Läsionen zu identifizieren, die Häufigkeit einer zur Diagnosestellung erforderlichen Erweiterung der Diagnostik und die Anzahl interdisziplinär diagnostizierter Fälle (interdisziplinärer Diagnose Tumorzentrum, IDT) im Vergleich zur Einweisungsdiagnose (ED) und radiologischen Diagnose (RD) zu beschreiben.

Material und Methoden: 413 Patienten mit 272 BKT und 141 TLL wurden nachuntersucht. Die Häufigkeit „gestellter" vs. „deskriptiver" Diagnosen wurde getrennt nach ED, RD, IDT und Histologie wie auch der Anteil einer erweiterten Diagnostik (Bildgebung, Biopsie) untersucht.

Ergebnisse: Bei radiologisch diagnostizierten BKT war die ED in 56, die RD in 81 % gleich der IDT mit hier bei 29 % ergänzter Bildgebung. 21 % (12 % zur

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Diagnosestellung) wurden biopsiert, hierbei entsprach die ED in 40, die RD in 60 und die IDT in 76 % der Histologie. Bei radiologisch diagnostizierten TLL war die ED in 32, die RD in 61 % gleich der IDT mit hier in 21 % erweiterter Bildgebung; eine Biopsie lag bei 36 % vor (zur Diagnosestellung bei 27 %), dabei entsprach dieser die ED in 20, die RD in 27 und die IDT in 51 %. Diagnostische Schwierigkeiten traten v. a. beim Enchondrom, nicht ossifizierenden Fibrom (NOF), der solitären (SKZ) und aneurysmalen Knochenzyste (AKZ) auf. Das Ganglion wurde häufig als Tumor interpretiert.

Schlussfolgerung: Bei TLL bestehen größere differenzialdiagnostische Schwierigkeiten als bei BKT. Durch die interdisziplinäre Synopse von Klinik, Radiologie und ggf. Pathologie kann eine tragfähige Diagnose gestellt werden.

Introduction

In many instances, benign bone tumors (BBT) and tumor like-lesions (TLL) of the bone can be diagnosed solely through conventional X-rays and require no biopsies for clarification [1 – 3].

These entities are categorized according to WHO classification [4]. Among benign bone tumors, osteochondroma are the most common followed by chondroma, while solitary bone cysts are the most common tumor-like lesions (**Table 1**) [2, 5].

Nevertheless, making a diagnosis can pose a challenge for orthopedists, trauma surgeons, radiologists and last, but not least, pathologists [6, 7]. For example, an aneurysmatic bone cyst must be differentiated not only from a solitary bone cyst, but also in particular from telangiectatic osteosarcoma [5, 8]. Because of possible malignant transformation, many tumors require structured preventative care [9]. If nothing else, this necessitates establishing a sound diagnosis through imaging and clinical findings and, if necessary, histological examination.

Table 1 Classification and prevalence of benign bone tumors and tumor-like lesions.

primary benign bone tumors	prevalence in %
ossifying tumors	
– osteoma	< 1
– osteoid osteoma	10
– osteoblastoma	3
cartilaginous tumors	
– osteocartilaginous exostosis/osteochondroma	48
– chondroma	23
– chondroblastoma	5
– chondromyxoid fibroma	2
vascular tumors	
– hemangioma	4
fibrogenic and fibrohistiocytic tumors	
– desmoid tumor (fibromatosis)	< 1
– non-ossifying fibroma (NOF)	10
– benign fibrous histiocytoma	2
tumor-like lesions	
– solitary bone cyst	12
– aneurysmatic bone cysts	< 1
– fibrous dysplasia	< 1
– osteofibrous dysplasia	< 1

BBT and TLL treated at a center were retrospectively examined in the present study. In addition to the absolute number of definitive versus “descriptive diagnoses” being determined, diagnoses were compared to one another grouped as diagnosis upon referral (ED), radiologist's diagnosis (RD), interdisciplinary tumor center diagnosis (IDT) and, if present, histological diagnosis. The goal of the study was to identify difficult-to-assess lesions and examine the prevalence of advanced diagnostics to yield a diagnosis (imaging and/or biopsy) as well as the number of interdisciplinary diagnosed cases (IDT) compared to ED and RD.

Material and methods

The records of 272 patients with BBT and 141 patients with TLL treated at a center over a four-year period were retrospectively evaluated. As the basis of this study, diagnoses of BBT and TLL, respectively, were established interdisciplinarily through clinical-radiological examination and/or histological analysis, wherein ED and RD could also include malignant, degenerative or infectious processes.

Lesions were classified according to WHO radiological and histological criteria [4]. **Table 2** provides an overview of typical clinical and radiological criteria.

If there were multiple outpatient visits, the initial visit was recorded. If further tests were run, the subsequent visit was included in the evaluation with only a single record being kept overall.

It was examined which diagnostics (conventional X-rays, CT, MRI) were used during the initial visit to the center and for which entities further imaging or biopsy was performed to establish diagnosis.

Furthermore, the ED, RD, IDT including “descriptive diagnosis” and, if present, histological diagnoses were compared to one another. The radiological report for the RD was issued by another examiner than the report issued for the IDT. The present analysis is thus based on the interobserver variability of radiologists operating independently of one another. A “descriptive diagnosis” was defined as “unspecific radiomorphological description of a bone lesion" without an actual diagnosis being established. Given the rising number of definitive diagnoses (ED < RD < IDT), the IDT superseded the RD and the RD the ED value-free in this process. If a histological analysis was present, it defined the diagnosis (gold standard).

Evaluation was performed separately for BBT and TLL with as well as without histological study. Purely “descriptive diagnoses” were classified in the evaluation as “discrepant”, so that the results contain cases with the following criteria: 1. At least one of the diagnoses (ED, RD, IDT) is descriptive. 2. A different evaluation ("discrepant diagnoses”) was made in the ED, RD, IDT and/or histology. 3. The diagnosis was established purely through histology.

Results

Below, the results are described separately for BBT and TLL, and a detailed evaluation can be found in the indicated tables. The entities specified in the text are abbreviated as follows (in alphabetical order): ABC: aneurysmal bone cyst,

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Table 2 Survey of typical clinical and radiological criteria concerning benign bone tumors and tumor-like lesions of the bone.

BBT/TLL (alphabetic)	primary manifestation age	primary location	clinical signs	radiological signs
benign bone tumors				
enchondroma	any age	minor long bones in the hands and feet, major long bones	no pain, usually incidental finding	radiopaque, often purely lytic, calcification focus (matrix)
hemangioma	0 – 60	skull, spinal column	very seldom pain	osteolytic, honeycomb-like
non-ossifying fibroma (NOF)	0 – 20	metaphysis of major long bones	usually no complaints, pain when there is an imminent/ materialized fracture	eccentric, osteolytic, wavy marginal sclerosis
osteochondroma	10 – 30	metaphysis of the major long bones, also flat bones	local, mechanically triggered complaints in soft tissues	standing tall or squat on the bones, "seamlessly" emanates from the spongiosa of the mother bone.
osteoid osteoma	10 – 20	major long bones	pronounced pain at night, typically responsive to aspirin	cortical, centrally lytic with extensive circumscribing sclerosis, (central) calcification of the nidus possible
tumor-like lesions				
aneurysmatic bone cyst (ABC)	10 – 20	metaphysis of major long bones, spinal column	moderate pain at night, local dull pain	eccentric, osteolytic, blow-out
fibrous bone dysplasia (Jaffe-Lichtenstein)	5 – 15	skull, ribs, metaphysis of the major long bones of the lower extremities	usually no pain, localized complaints accompanying (initial) deformation	diffuse-cloudy, "frosted glass" appearance, deforming
osteofibrous dysplasia (Campanacci)	0 – 15	tibia, fibula	localized pains	multilocular lytic-sclerotic, honeycomb-stringy pattern, "bowing" of the tibia
solitary bone cyst (SBC)	0 – 20	major long bones	occasional pressure-like/dull pain when there is an imminent/materialized fracture	cystic-expansive, centrally located in the bone, narrow marginal sclerosis

EC: enchondroma, EG: eosinophilic granuloma, FD: fibrous dysplasia, H: hemangioma, IG: intraosseous ganglion, NOF: non-ossifying fibroma, OC: osteochondroma, OO: osteoid osteoma, SBC: solitary bone cyst

Benign bone tumors without histology. A total of 214 cases were diagnosed through imaging. Imaging was available during initial visit to the center: 44× conventional X-ray, 8× CT, 48× MRI, 80× conventional X-ray and MRI, 10× MRI and CT, 8× conventional X-ray and CT, 8× conventional X-ray, MRI and CT and 8× no (current) imaging.

Overall, 128 cases (60%) were diagnosed in the ED, 176 (82%) in the RD and 214 (100%) in the IDT (**Table 3, 4**). Among these figures, 118 identical diagnoses (55%) were made, while discrepant diagnoses were present in 96 cases (45%), primarily in the case of enchondroma and NOF (**Table 5, 6**). The number of diagnoses issued thus rose between ED and RD and between RD and IDT, with supplemental imaging being performed in IDT in 61 of 214 cases (29%) particularly for the following entities: EC (15×), NOF (13×), OC (11×) and H (5×).

Benign bone tumors with histology. Imaging was performed during initial visit to the center in 58 cases: 8× conventional X-ray, 16× MRI, 23× conventional X-ray and MRI, 5× MRI and CT, 2× conventional X-ray and CT, 8× conventional X-ray, MRI and CT. Supplemental imaging was performing in 16 of 58 cases (28%) to establish diagnosis (IDT), particularly for OC (5×), OO (3×), NOF (2×) and EC (2×).

In total, 27 cases (60%) were diagnosed morphologically through imaging in the ED, 35 (82%) in the RD and 53 (91%) in the IDT. Among these figures, 21 identical diagnoses (36%) were made, while discrepancies were present in between ED, RD, IDT and histological diagnoses, respectively, in 37 of 58 cases (**Table 3, 4**). A biopsy was taken in 33 of 58 cases (57%) as well as in 12% of all 272 cases of benign bone tumors to confirm diagnosis, particularly in cases of EC (11×) and NOF (5×) and in 25 cases when surgery was performed following diagnosis previously established through imaging.

Thus in total, ED including "descriptive diagnosis" did not match the histologically definitive diagnosis in 35 of 58 cases (60%), while the same was true of RD and IDT in 23 of 58 cases (40%) and 14 of 58 cases (24%), respectively (**Table 5, 6**).

Tumor-like bone lesions without histology. A total of 90 cases were diagnosed through imaging. Imaging was available during the initial visit to the center. 18, 6× CT, 19× MRI, 30× conventional X-ray and MRI, 3× conventional X-ray and CT, 8× MRI and CT, 8× conventional X-ray and CT and 6× conventional X-ray, MRI and CT. Diagnoses were established in ED in 35 (39%), in RD in 58 (64%) and in IDT in 90 cases (100%) (**Table 3, 4**), of which 29 (32%) were identical. Discrepancies were present in 61 cases (68%), 6 of which (10%) were diagnosed in the ED, 29 (48%) in the RD and 61 (100%) in the IDT. Supplemental imaging (IDT) was performed in 19 of 90 cases (21%), particularly when IG (9×) was present, which was frequently interpreted initially as TLL or tumor.

The number of definitive diagnoses thus rose between ED and RD and between RD and IDT. Including "descriptive" diagnoses, ED did not correspond to IDT in 61 of 90 cases (68%), the same being true for RD in 35 of 90 cases (39%) (**Table 5, 6**), particularly for SBC, ABC, FD and IG (**Table 5, 6**)

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	benign bone tumors (n = 272)		tumor-like lesions (n = 141)	
	without histology (n = 214) in %	with histology (n = 58) in %	without histology (n = 90) in %	with histology (n = 51) in %
ED	60	47	39	35
"descriptive diagnosis"	40	53	61	65
RD	82	60	64	43
"descriptive diagnosis"	18	40	36	57
IDT	100	91	100	90
"descriptive diagnosis"	–	9	–	10
identical diagnoses (ED, RD, IDT)	55	36	32	18
discrepant diagnoses (ED, RD, IDT including "descriptive diagnoses")	45	64	68	82
histology –				
agrees with ED	–	40	–	20
agrees with RD	–	60	–	27
agrees with IDT	–	76	–	51

ED = diagnosis upon referral, RD = radiological diagnosis, IDT = interdisciplinary tumor center diagnosis.

Table 3 Distribution of "descriptive" and definitive diagnoses for benign bone tumors and tumor-like lesions and frequency of identical and discrepant diagnoses:

discrepant diagnoses	benign bone tumors		tumor-like lesions	
	without histology (n = 96) in %	with histology (n = 37) in %	without histology (n = 61) in %	with histology (n = 42) in %
total number of ED as discrepant diagnoses	10	16	10	21
discrepant diagnoses (including "descriptive diagnoses") ED to IDT	99	–	100	–
total number of RD as discrepant diagnoses	60	38	48	31
discrepant diagnoses (including "descriptive diagnoses") RD to IDT	42	–	57	–
total number of IDT as discrepant diagnoses	100	86	100	88

ED = diagnosis upon referral, RD = radiological diagnosis, IDT = interdisciplinary tumor center diagnosis

Table 4 Distribution of discrepancies in diagnoses for benign bone tumors and tumor-like lesions.

Tumor-like bone lesions with histology. Imaging was present during initial visit to the center in 51 cases: 5 × conventional X-ray, 9 × MRI, 21 × conventional X-ray and MRI, 3 × conventional X-ray and CT, 8 × MRI and CT, 3 × conventional X-ray, MRI and CT. Supplemental imaging (MRI/CT/conventional, non-contrast X-rays) was performing in 11 of 51 cases (22 %) to establish diagnosis (IDT), this being true for ABC (5x) and for SBC, IG and FD in 2 instances each.

In total, 18 cases (35 %) were diagnosed through imaging in the ED, 22 (43 %) in the RD and 46 (90 %) in the IDT. Of this number, 9 identical diagnoses were established. Discrepant diagnoses were present in 42 of 51 cases (72 %) (**Table 3, 4**), this being true especially for ABC (16 ×), SBC (11x) as well as IG (6 ×).

A biopsy was taken to establish diagnosis in 38 of 51 cases (75 %) as well as in 27 % of all 141 cases of tumor-like lesions, this most frequently being performed for ABC (17 ×), SBC (7 ×), FD (5 ×) and IG (5 ×). In 13 cases, the biopsy was taken as routine procedure during surgery and not for actually establishing diagnosis.

In total, ED including "descriptive diagnosis" did not correspond to histology in 41 of 51 cases (80 %), while the same was true of RD and IDT in 37 of 51 cases (73 %) and 25 of 51 cases (49 %), respectively. In this context the following entities were diagnosed purely through histology: IG (2 ×) and ABC, FD and EG in 1 case each (**Table 5, 6**).

Discussion

Benign bone tumors and tumor-like lesions can be difficult to diagnose. However, establishing a diagnosis is imperative for creating a sound treatment concept and/or being able to confirm the harmlessness of the lesion [1, 10]. In everyday medical practice, benign lesions have a higher incidence than malignant bone tumors, the latter being seen statistically 1 to 2 times in an orthopedist's or trauma surgeon's career [7].

Many lesions are detected incidentally [11]. At an aggressive stage, they can trigger complaints [12, 13], the two most common symptoms being pain and palpable swelling [1, 10]. The characteristic pains for BBT and TLL are summarized in **Table 2**.

According to clinical and radiological experience, the better part of bone lesions can be diagnosed solely based on conventional X-rays and symptoms [1, 8, 14]. The interdisciplinary review is helpful, sensible and usually necessary in

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Table 5 Number and type of diagnoses (AD, RD, IDT) of benign bone tumors and tumor-like lesions with/without histology.

cases	ED	RD	IDT	histology	discrepancy ED vs. RD	discrepancy ED vs. IDT	discrepancy RD vs. IDT	discrepancy ED vs. histo	discrepancy RD vs. histo	discrepancy IDT vs. histo
benign bone tumors without histology										
96	n = 10	n = 58	n = 96	–	n = 4	n = 9	n = 2	–	–	–
	3 EC, 2 OC, 1 FD, 1 H, 1 CB, 1 BFH, 1 OO	14 EC, 11 OC, 12 NOF, 10 H, 1 C, 1 L, 1 M, 2 OCE, 3 O, 3 OO	26 EC, 12 OC, 27 NOF, 13 H, 2 C, 3 L, 2 OCE, 4 O, 3 OO, 2 SC, 2 BFH		1 EC, 1 EC, 1 H, 1 NOF	5 NOF, 2 EC, 1 H, 1 O	1 NOF, 1 O			
benign bone tumors with histology										
37	n = 6	n = 14	n = 32	n = 37	n = 1	n = 3	n = 1	n = 4	n = 0	n = 9
	1 CS, 1 BA, 2 EC, 1 OO, 1 OB	9 OC, 3 EC, 2 OO	5 EC, 3 NOF, 2 CMF, 1 CB, 3 CS, 2 L, 10 OC, 4 OO, 1 OC, 1 BA	10 EC, 5 NOF, 1 BFH, 2 L, 10 OC, 4 OO, 1 SC, 2 C, 2 H	1 OO	1 CS, 1 OO, 1 L	1 CS	1 C, 1 EC, 1 L, 1 OO		5 EC, 1 NOF, 1 BFH, 1 SC, 1 C
tumor-like bone lesions without histology										
61	n = 6	n = 29	n = 61	–	n = 0	n = 6	n = 3	–	–	–
	3 OO, 2 EC, 1 BM	16 IG, 5 FD, 2 ABC, 2 SBC, 2 EG, 1 NOF, 1 OO	29 IG, 17 FD, 2 ABC, 11 SBC, 2 EG			4 IG, 2 FD	1 IG, 1 FD, 1 SBC			
tumor-like bone lesions with histology										
42	n = 9	n = 13	n = 37	n = 42	n = 3	n = 6	n = 0	n = 8	n = 8	n = 20
	2 SBC, 1 OC, 1 FD, 1 BM, 1 BI,1 CS, 1 NOF, 1 L	3 SBC, 3 ABC, 1 IG, 1 FD, 1 CB, 1 OB, 2 EC, 1 L	11 ABC, 8 SBC, 3 IG, 3 FD, 2 OB, 1 OS, 2 OC, 1 C, 2 CB, 1 BI, 2 EC, 1 L	16 ABC, 11 SBC, 6 IG 5 FD, 3 EG, 1 LG	1 EC, 1 ABC, 1 L	3 ABC, 1 CB, 1 EC, 1 L		5 ABC, 1 LG, 1 FD, 1 SBC	3 ABC, 2 FD, 1 IG 2 SBC	9 ABC, 4 SBC, 3 FD, 2 EG, 1 LG, 1 G

ED = diagnosis upon referral, RD = radiological diagnosis, IDT = interdisciplinary tumor center diagnosis ABC = aneurysmatic bone cyst, BA = Brodie abscess, BFH = benign fibrous histiocytoma, C = chondroma, CB = chondroblastoma, CMF = chondromyxoid fibroma, CS = chondrosarcoma, EC = enchondroma, EG = eosinophilic granuloma, FD = fibrous dysplasia, H = hemangioma, IG = intraosseous ganglion (for reason of practicability categorized as TLL), BI = bone infarction, BM = bone metastasis, L = lipoma, LG = lipoid granulomatosis, M = melorheostosis, NOF = non-ossifying fibroma, O = osteoma, OB = osteoblastoma, OC = osteochondroma, OCE = osteochondromatosis, OO = osteoid osteoma, OC = Osteoclastoma, SC = synovial chondromatosis, SBC = solitary bone cyst.

Table 6 Quantity of discrepant diagnoses with/without histology according to entity (cases n ≥ 5).

	without histology			with histology		
	total no. (absolute)	number of identical dg. of total dg. in%	number of discrepant dg. of total dg. in%	total no. (absolute)	number of identical dg. of total dg. in%	number of discrepant dg. of total dg. in%
benign bone tumors	214	55	45	58	36	64
enchondroma	70	63	37	11	9	91
osteochondroma	47	74	26	18	44	56
NOF	36	31	69	5	0	100
hemangioma	18	28	72	3	33	66
osteochondromatosis	9	78	22	4	100	0
tumor-like lesions	90	32	68	51	18	82
intraosseous ganglion	35	17	83	9	33	67
fibrous dysplasia	23	26	74	5	0	100
solitary bone cyst	15	27	73	13	2	85
aneurysmatic bone cyst	6	67	33	20	20	80
eosinophilic granuloma	6	67	33	3	0	100

Dg. = diagnoses.

this context, with many cases requiring additional imaging to establish diagnosis [2, 5].

The radiological-diagnostic procedure is divided into 3 segments: 1. detecting the lesion, 2. diagnosing 3. staging (for malignant tumors). As a starting point, conventional X-rays provide information on the location, the margins, the periosteum and the aggressiveness (Lodwick classification) [2, 15]. MRI facilitates evaluation of medullary space, matrix and soft tissues. CT likewise allows description of the matrix (e. g. calcification) and is the best method for assessing cortical structures, particularly in anatomically challenging regions (e. g. pelvis, spinal column) [2]. A sensitive, yet unspecific method, skeletal scintigraphy is occasionally still used for further diagnostics, e. g. in cases of osteoid osteoma.

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By evaluating the number of "definitive" versus "descriptive diagnoses" taking into account the ED, RD and IDT, the present study examined which lesions posed diagnostic challenges, which were subjected to further imaging diagnostics and/or a biopsy and which were soundly diagnosed through interdisciplinary assessment.

Of 272 benign bone tumors, 155 were diagnosed through ED, 211 through RD and 267 through IDT. The number of diagnosed and not purely descriptive entities thus increased between ED and RD and between RD and IDT, with further imaging being performed in 77 of 272 cases (28 %) to establish a diagnosis (IDT), this occurring most frequently in cases of EC and NOF, in cases of OC for surgical planning (expansion of the cartilage cap) and not for confirming the diagnosis. Among the entities morphologically evaluated through imaging, 55 % of the diagnoses were identical and 45 % were discrepant, with the ED and RD matching the IDT 1 % and 58 % of the time, respectively, in discrepant cases.

For 21 % of BBT a histological diagnosis was present. Collectively, 36 % were identical and 64 % discrepant, with ED, RD and IDT corresponding to the histological diagnosis in 40 %, 60 % and 76 % of cases, respectively. However, a biopsy was taken for actual confirmation of diagnosis in only 33 of 272 cases (12 %), this likewise being performed here most frequently for EC and NOF (side note: For reasons of practicality, the NOF as an actual ossification disturbance was categorized as a bone tumor). In all other cases, biopsies were taken as a routine part of surgery.

The heterogeneity of the differential diagnoses for the entities discrepantly diagnosed through imaging as well as through imaging and biopsy, as shown in the tables and the results section, leads to the conclusion that there is no systematic confusion of diagnoses, but rather that a lesion by nature cannot always be diagnosed with certainty.

Fig. 1 shows an example of a histologically confirmed NOF that was biopsied due to conventional X-rays and CT showing cortical destruction. In the study by Blaz et al. the variable stage-dependent radiologically visible morphology was discussed as a possible cause of the difficulties in diagnosing NOF [16].

Fig. 2 shows a histologically confirmed enchondroma. A Brodie abscess was suspected based on non-contrast radiological images and MRI showing a lesion demarcated by marginal sclerosis with T1-weighted hypointense interior signal and peripheral contrast medium uptake. Thus an enchondroma missing the typical "popcorn-like" calcification of the matrix can be misinterpreted as a cystic lesion [2, 17, 18].

In the authors' view, different reasons for the "descriptive" and discrepant diagnoses must be discussed:

1. Only lesions of unclear morphology when imaged are referred to a center. 2. The radiologists are not provided with the necessary clinical data including symptoms, which are frequently the key to correctly interpreting the findings. [19]. 3. For imaging diagnostics, pure cross-sectional imaging (MRI/CT) was available, i. e. not the non-contrast conventional X-rays often critical for diagnosis. 4. A larger number of treated patients and the option of interdisciplinary exchange of knowledge at a center can explain the higher proportion of definitive diagnoses. 5. Searching the ICD codes for a specific entity is more time-consuming than using the descriptive diagnosis "bone tumor".

Of the 141 tumor-like bone lesions 53 were diagnosed in the ED, 80 in the RD and 136 in the IDT. The portion of diagnosed and not purely descriptive entities thus rose in the case of TLL as well between ED and RD and between RD and IDT, with further imaging becoming necessary in 30 of 141 cases (21 %) for establishing a diagnosis (IDT), this being performed most frequently for IG, FD, SBC and ABC.

When it came to the entities assessed morphologically through imaging, 32 % identical and 68 % discrepant diagnoses were established. Overall, the ED and RD matched the IDT 32 % and 61 % of the time, respectively.

TLL was diagnosed histologically in 36 % of cases. Overall, 18 % of diagnoses were identical and 82 % discrepant, with ED, RD and IDT matching the histological diagnosis 20 %, 27 % and 51 % of the time, respectively. To confirm diagnosis, however, a supplemental biopsy was taken in only 38 of 141 cases (27 %) (otherwise as a routine part of surgery when clinical symptoms were present).

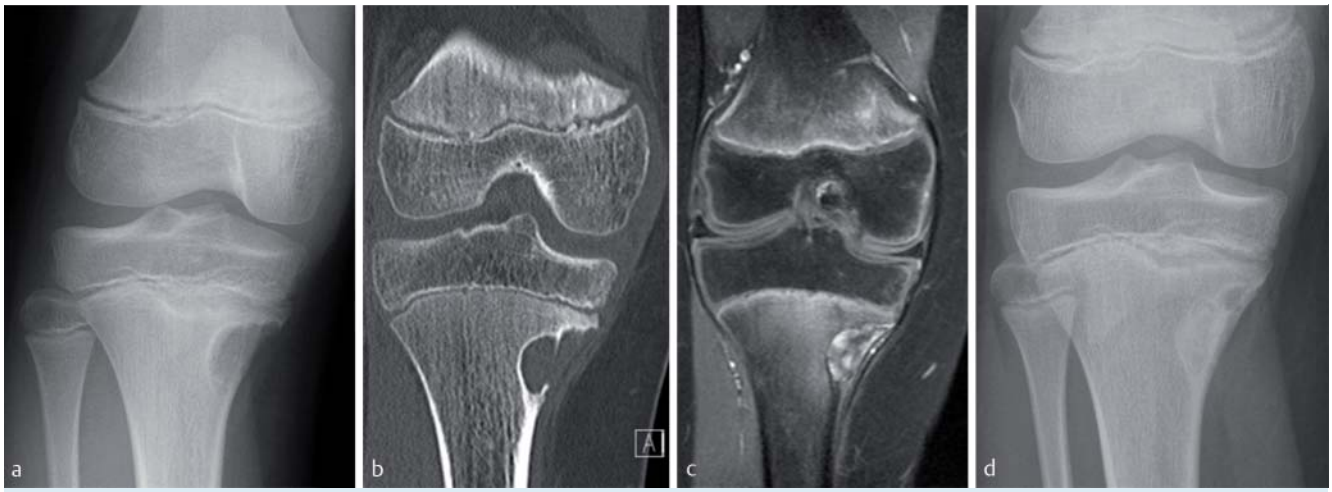

Fig. 1 Histologically confirmed non-ossifying fibroma in a 14 year old child's tibia. **a** A.p. X-ray of the right knee shows an eccentrically located metaphyseal osteolysis with marginal sclerotic demarcation without definable exterior cortical bone, **b** associated CT. **c** In MRI (T2) inhomogeneous marble-cake-like signal enhancement. **d** Progressed healing with increasing diaphyseal sclerotization.

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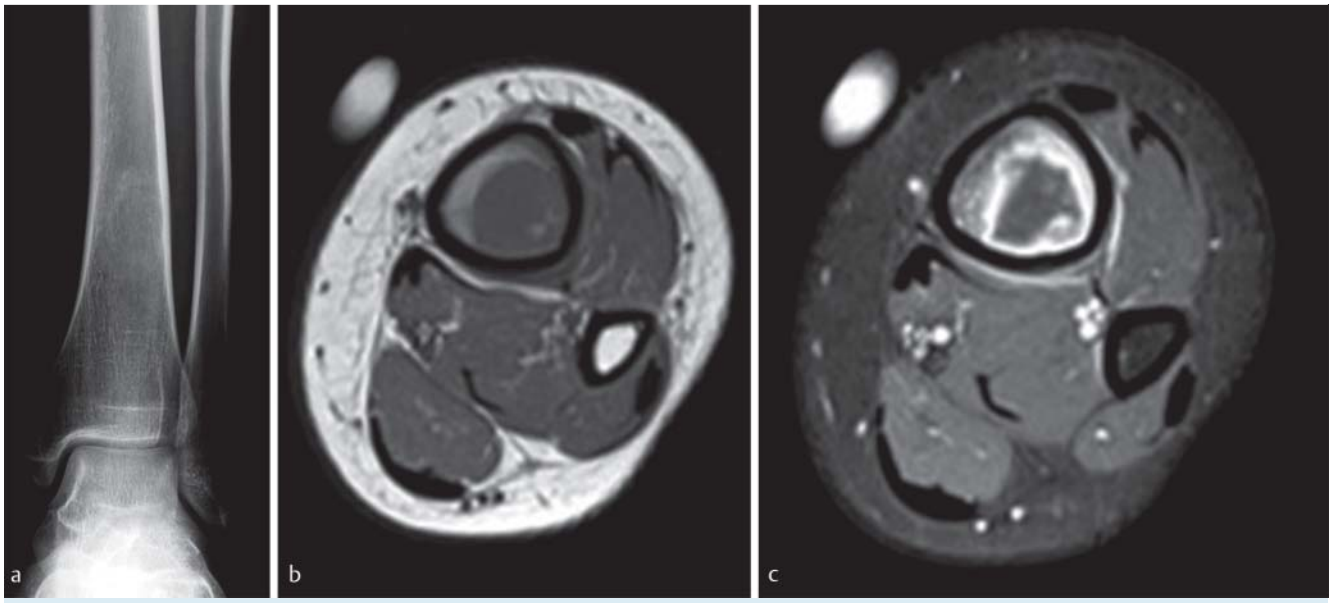

Fig. 2 Histologically confirmed enchondroma in a 23 year old female patient's tibia. **a** Slightly eccentric tibial lesion, surrounded by a blurred marginal sclerosis. **b** T1-weighted MRI in transverse view showing verifiable hypointense lesion located in the medullary space without cortical erosion. **c** The lesion exhibiting a predominantly peripheral contrast enhancement in the T1 fat-saturated sequence with contrast medium (in **b** and **c** nitrate capsule for external marking of the specified complaints).

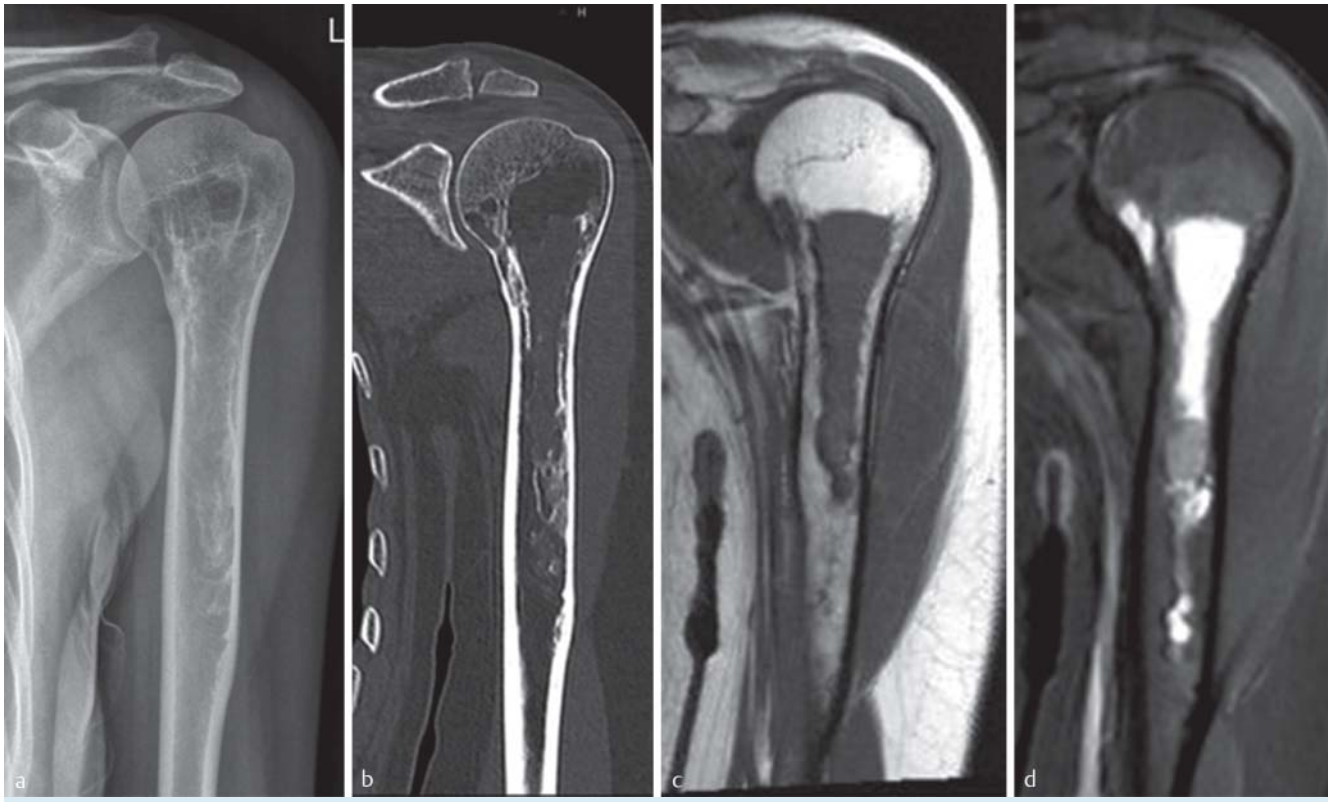

Fig. 3 Histologically confirmed solitary bone cyst with regressive changes in a 45-year old female patient's left humerus. **a** Conventional X-ray of the left humerus and **b** CT showing meta-diaphyseal centrally located cyst demarcated by marginal sclerosis. **c** T1-weighted MRI showing homogeneously reduced signal, **d** T2-weighted image showing predominantly hyperintense signal with focal hypointensity.

The percentage of definitive diagnoses is thus comparable with the percentages for "benign bone tumors". The percentage of discrepant diagnoses is higher (73 % versus 49 %), as is the percentage of undiagnosed and misdiagnosed entities when compared against histology.

As with BBT, it must also be discussed for TLL to what extent only lesions of unclear morphology upon imaging were ul-

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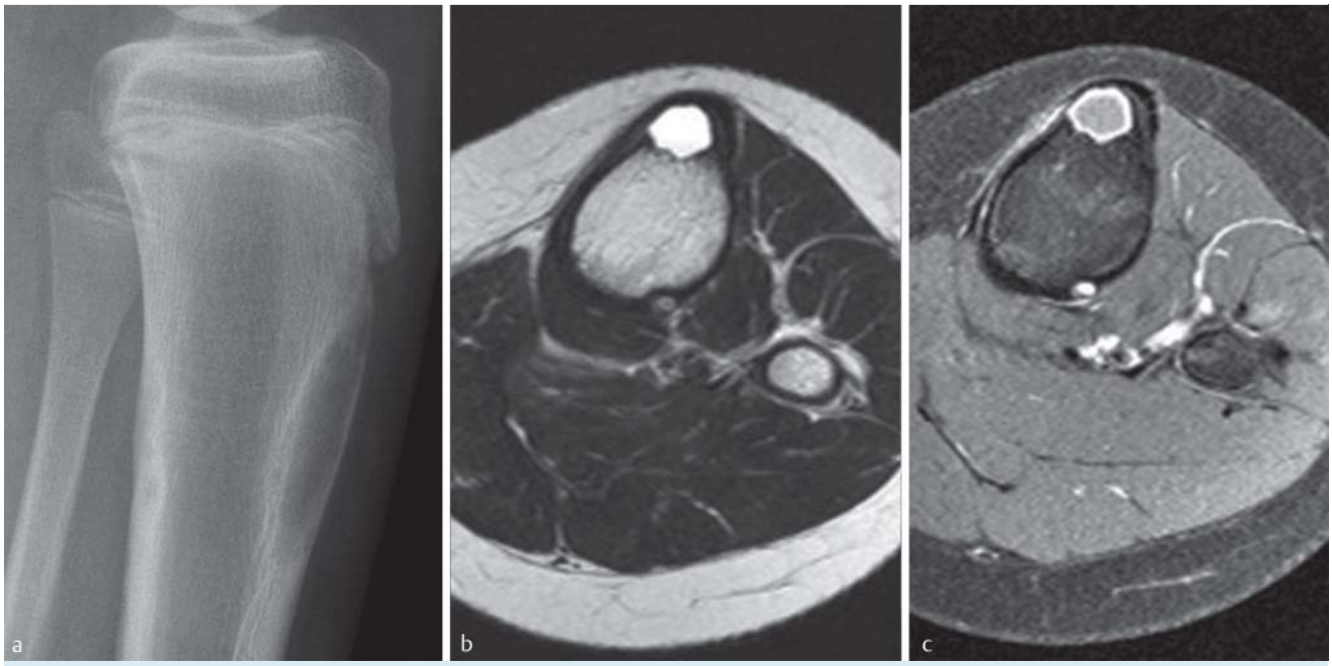

Fig. 4 Histologically confirmed aneurysmatic bone cyst in a 16-year old female patient's tibia. **a** A conventional X-ray of the left knee joint in lateral projection showing an eccentrically located meta-diaphyseal lesion, demarcated by a slight marginal sclerosis in the direction of the marrow. **b** MRI (T2, turbo-spin echo sequence) showing a distinct signal enhancement of the aneurysmatic bone cyst. **c** MRI (T1, fat-saturated with contrast medium) showing a distinct peripheral uptake of contrast medium.

timately referred to a center, which would be causal for the aforementioned discrepancies. It can be further concluded from the results in addition to the reasons specified for the benign bone tumors that a differential diagnostic classification of cystic lesions fundamentally cannot be simple, wherein with the exception of ganglion in the sense of a degenerative lesion, TLLs such as SBC, ABC and FD pose the greatest difficulties in the larger picture.

Fig. 3 shows a centrally located SBC demarcated by marginal sclerosis, which comes across on MRI in T1-weighted images as hypointense and in T2-weighted images as hyperintense with focally hypointense areas with regressive change.

Fig. 4 shows an ABC. If the eccentric location and the blow-out phenomena are not clearly visible as characteristic signs, the lesion can be confused with an SBC or FD [18, 20, 21].

Conversely, however, the diagnosis of cystic lesions can be narrowed down through evaluating non-contrast conventional X-rays (topography, periosteum, multiplicity, base substance, growth rate according to Lodwick [22]) and factoring in age and clinical findings [22], with cross-sectional imaging providing important additional information for definitive diagnosis particularly in the case of these lesions.

Limitations of the study

It is possible that only patients with unclear bone lesions and/or complaints were referred to a center to clarify whether surgery was indicated (selection bias). Differing incidences of the entities having an influence on the results would also have to be discussed. In addition, the radiologists were furnished in many cases with no or only marginal information on clinical findings/symptoms necessary for assessment, thereby compromising evaluation and resulting in "descriptive diagnoses".

Because an entity was determined at the center on the basis of imaging in many cases, histological validation was not performed. Nevertheless, a sound interdisciplinary diagnosis was yielded for further decisions on therapy, which satisfied the goal set by the medical office and the hospital of not biopsying and thereby "over-diagnosing" each lesion.

Clinical relevance

Benign bone tumors and tumor-like lesions can pose a challenge as the present study has shown through the prevalence of "descriptive diagnoses". Diagnostic challenges can appear in the case of tumor-like lesions especially for SBC, ABC and FD and in the case of benign bone tumors particularly for EC and NOF. Imaging with MRI/CT in addition to non-contrast conventional X-rays can be necessary for establishing a diagnosis. Cross-sectional imaging can supplement the non-contrast conventional X-rays normally constituting basic diagnostics.

Interdisciplinary discussion of these findings factoring in medical history, clinical findings, radiology and any pathology facilitates a sound diagnosis, which allows decisions to be rendered concerning the necessity of follow-up examinations, a biopsy or clarifying the "non-need for treatment" of the lesion and reduces the risk of over-diagnosis or unnecessary surgical therapy.

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