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

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.

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.


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
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.

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

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


**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 IDT, and 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 performed 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)
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...
In 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 periosseum 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.

### Table 5

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

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

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 = intracortical ganglion (for reason of practicability categorized as TLL), BI = bone infarction, BM = bone metastasis, L = lipoma, LG = lipoid granulomatosist 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).

<table>
<thead>
<tr>
<th>Entity</th>
<th>without histology (absolute)</th>
<th>number of identical dg. of total dg. in%</th>
<th>number of discrepant dg. of total dg. in%</th>
<th>with histology (absolute)</th>
<th>number of identical dg. of total dg. in%</th>
<th>number of discrepant dg. of total dg. in%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>benign bone tumors</strong></td>
<td>214</td>
<td>55</td>
<td>45</td>
<td>58</td>
<td>36</td>
<td>64</td>
</tr>
<tr>
<td>enchondroma</td>
<td>70</td>
<td>63</td>
<td>37</td>
<td>11</td>
<td>9</td>
<td>91</td>
</tr>
<tr>
<td>osteochondroma</td>
<td>47</td>
<td>74</td>
<td>26</td>
<td>18</td>
<td>44</td>
<td>56</td>
</tr>
<tr>
<td>NOF</td>
<td>36</td>
<td>31</td>
<td>69</td>
<td>5</td>
<td>0</td>
<td>100</td>
</tr>
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<td>28</td>
<td>73</td>
<td>3</td>
<td>33</td>
<td>66</td>
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<td>osteochondromatosis</td>
<td>9</td>
<td>78</td>
<td>22</td>
<td>4</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>tumor-like lesions</td>
<td>90</td>
<td>32</td>
<td>68</td>
<td>51</td>
<td>18</td>
<td>82</td>
</tr>
<tr>
<td>intraosseous ganglion</td>
<td>35</td>
<td>17</td>
<td>83</td>
<td>9</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td>fibrous dysplasia</td>
<td>23</td>
<td>26</td>
<td>74</td>
<td>5</td>
<td>0</td>
<td>100</td>
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<tr>
<td>solitary bone cyst</td>
<td>15</td>
<td>27</td>
<td>73</td>
<td>13</td>
<td>2</td>
<td>85</td>
</tr>
<tr>
<td>aneurysmatic bone cyst</td>
<td>6</td>
<td>67</td>
<td>33</td>
<td>20</td>
<td>20</td>
<td>80</td>
</tr>
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<td>eosinophilic granuloma</td>
<td>6</td>
<td>67</td>
<td>33</td>
<td>3</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Dg. = diagnoses.
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 subject 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).
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-

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.
ultimately 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.

**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.

**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.
Affiliations
1 Department of Orthopaedics and Traumatology, University Medical Centre Freiburg, Germany
2 Department of Diagnostic and Therapeutic Radiology, St. Josefshospital Freiburg, Germany
3 Department of Plastic and Hand Surgery, University Medical Centre Freiburg, Germany
4 Department of Pathology, University Medical Centre Freiburg, Germany
5 Department of Orthopaedics and Traumatology/Comprehensive Cancer Centre Freiburg CCCF, University Medical Centre Freiburg, Germany

References
4 Fletcher CDM, Bridge JA, Hogendoorn P et al. (eds) WHO Classification of Tumours of Soft Tissue and Bone. Lyon: IARC-Press; 2013
7 Hardes J, Gosheger G, Streibburger A. Benigne Tumoren der Bewegungsorgane. Orthopädie und Unfallchirurgie up2date 2014; 5: 307 – 335
19 Wiens J. Gutartige Knochentumoren und „tumor-like lesions“. Was muss der Kliniker über die Bildgebung wissen? Unfallchirurg 2014; 117: 863 – 872