Thieme

Diagnostic Delay in Patients with Osteoid Osteoma

Diagnostischer Delay bei Patienten mit Osteoidosteom

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ABSTRACT

Purpose To assess diagnostic delay in patients with osteoid osteoma and to analyze influencing factors.

Materials and Methods All patients treated for osteoid osteoma at our tertiary referral center between December 1997 and February 2021 were retrospectively identified (n = 302). The diagnosis was verified by an expert panel of radiologists and orthopedic surgeons. The exclusion criteria were post-interventional recurrence, missing data on symptom onset, and lack of pretherapeutic CT images. Clinical parameters were retrieved from the local clinical information system. CT and MR images were assessed by a senior specialist in musculoskeletal radiology.

Results After all exclusions, we studied 162 patients (mean age: 24 ± 11 years, 115 men). The average diagnostic delay was 419 ± 485 days (median: 275 days; range: 21–4503 days). Gender, patient age, presence of nocturnal pain, positive aspirin test, extent of bone sclerosis, and location of the tumor within bone and relative to joints did not influence diagnostic delay ($p > 0.05$). It was, however, positively correlated with nidus size ($r = 0.26$; $p < 0.001$) and was shorter with affection of long tubular bones compared to all other sites ($p = 0.04$). If osteoid osteoma was included in the initial differential diagnoses, the diagnostic delay was also shorter ($p = 0.007$).

Conclusion The diagnostic delay in patients with osteoid osteoma is independent of demographics, clinical parameters, and most imaging parameters. A long average delay of more than one year suggests low awareness of the disease among physicians. Patients with unclear imaging findings should thus be referred to a specialized musculoskeletal center or an expert in the field should be consulted in a timely manner.

Key Points

1. In this retrospective study of 162 patients treated for osteoid osteoma, the median diagnostic delay was 275 days (range: 21–4503 days).
2. Gender, age, presence of nocturnal pain, positive aspirin test, extent of bone sclerosis, and location of the tumor did not influence the diagnostic delay ($p > 0.05$).
3. Diagnostic delay was positively correlated with nidus size ($r = 0.26$; $p < 0.001$) and was shorter with affection of long tubular bones compared to all other sites (376 ± 485 vs. 560 ± 462 days; $p = 0.04$).

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ZUSAMMENFASSUNG

Ziel Evaluation des diagnostischen Delays bei Patienten mit Osteoidosteom sowie beeinflussender Faktoren.

Material und Methoden Alle Patienten, die zwischen Dezember 1997 und Februar 2021 in unserem tertiären Überweisungszentrum wegen eines Osteoidosteoms behandelt wurden, wurden retrospektiv identifiziert (n = 302). Die Diagnose wurde von einem Expertengremium aus Radiologen und Orthopäden gestellt. Ausschlusskriterien waren postinterventionelle Rezidive, fehlende Daten zum Symptombeginn und das Fehlen prätherapeutischer CT-Bilder. Klinische Parameter wurden aus dem lokalen klinischen Informationssystem abgerufen. CT- und MR-Bilder wurden von einem erfahrenen Spezialisten für muskuloskelettale Radiologie beurteilt.

Ergebnisse Nach allen Ausschlüssen wurden 162 Patienten (Durchschnittsalter 24 ± 11 Jahre, 115 Männer) analysiert. Der durchschnittliche diagnostische Delay betrug 419 ± 485 Tage (Median: 275 Tage; Range: 21–4503 Tage). Geschlecht, Alter, Vorhandensein nächtlicher Schmerzen, positiver Aspirin-Test, Ausmaß der Knochensklerose und Lage des Tumors innerhalb des Knochens und relativ zu den Gelenken hatten keinen Einfluss auf den diagnostischen Delay ($p > 0,05$). Er korrelierte jedoch positiv mit der Nidusgröße ($r = 0,26$; $p < 0,001$) und war im Vergleich zu allen anderen Lokalisationen kürzer in langen Röhrenknochen ($p = 0,04$). Wenn Osteoidosteome in die anfänglichen Differenzialdiagnosen einbezogen wurden, war der diagnostische Delay ebenfalls kürzer ($p = 0,007$).

Schlussfolgerung Der diagnostische Delay bei Patienten mit Osteoidosteom ist unabhängig von demografischen Merkmalen, klinischen Parametern und den meisten Bildgebungsparametern. Eine langer durchschnittlicher Delay von mehr als einem Jahr deutet auf ein geringes Bewusstsein unter Ärzten für die Krankheit hin. Patienten mit unklaren Bildbefunden sollten daher rechtzeitig an ein spezialisiertes muskuloskelettales Zentrum überwiesen oder ein Experte konsultiert werden.

Kernaussagen

1. In dieser retrospektiven Studie mit 162 Patienten, die wegen eines Osteoidosteoms behandelt wurden, betrug der mittlere diagnostische Delay 275 Tage (Range: 21–4503 Tage).
2. Geschlecht, Alter, Vorhandensein nächtlicher Schmerzen, positiver Aspirin-Test, Ausmaß der Knochensklerose und Lage des Tumors hatten keinen Einfluss auf den diagnostischen Delay ($p > 0,05$).
3. Der diagnostische Delay korrelierte positiv mit der Nidusgröße ($r = 0,26$; $p < 0,001$) und war im Vergleich zu allen anderen Lokalisationen kürzer in langen Röhrenknochen (376 ± 485 vs. 560 ± 462 Tage; $p = 0,04$).

ABBREVIATIONS

CT	Computed tomography
MR	Magnetic resonance
OO	Osteoid osteoma
RFA	Radiofrequency ablation

Introduction

Osteoid osteoma is the third most common benign bone tumor, accounting for approximately 10–12 % of primary bone tumors [1]. Adolescents and young adults are most commonly affected and nocturnal pain that responds well to nonsteroidal anti-inflammatory drugs is the most common symptom [2]. Delayed diagnosis and, thus, delayed therapy may result in an unnecessary exposure to pain as well as loss of function, scoliosis, osteoarthritis, and contractures [3–5]. Computed tomography (CT) is the imaging modality of choice for diagnosis because it can not only depict the typical appearance of the lesion but can also be used to define its exact location and to plan therapy [6]. The typical imaging appearance comprises a small lytic bone lesion (nidus) with a maximum diameter of 2 cm with various amounts of reactive sclerosis. While CT findings in the presence of typical clinical symptoms are pathognomonic for osteoid osteoma, magnetic resonance (MR) imaging is often chosen in current practice as the initial modality, mainly due to the lack of radiation exposure. Although MR imaging is sensitive, it is nonspecific and is often unable to identify the nidus [7]. Bone marrow edema as a typical associated finding of osteoid osteoma may thus be misinterpreted as a sequel of other pathologies [8, 9]. Therefore, the final diagnosis is often established by CT after considerable delay and repeated imaging, and, commonly, only upon presentation to a musculoskeletal tumor center. A previous study retrospectively assessed the morphologic changes of osteoid osteomas on CT scans in association with pain duration in a cohort of 96 patients [10]. The nidus mineralization ratio, which was calculated as the percentage of the calcification area over the total nidus area, increased with pain duration. However, associations with clinical parameters and MR-based imaging parameters were not assessed.

Therefore, the purpose of this study was to evaluate the diagnostic delay in patients with osteoid osteoma and the number of associated imaging procedures. In addition, the influence of various clinical parameters and imaging findings on the duration from first symptom onset to final diagnosis was evaluated.

Methods

Subjects

Institutional review board approval was obtained prior to this study (*BLINDED FOR REVIEW*). Written informed consent was waived for this retrospective analysis of routinely acquired imaging and clinical data. All patients treated for osteoid osteoma at our institution between December 1997 and February 2021 were retrospectively identified (n = 302). The diagnosis was verified by an expert panel of radiologists and orthopedic surgeons based on clinical and imaging findings. The exclusion criteria were postinterventional recurrence, missing data on symptom onset, and a lack of CT images (▶ **Fig. 1**).

Clinical data assessment

The following information was retrieved from the local clinical information system, if available: patient age at the time of diagnosis, gender, presence of nocturnal pain (yes/no), relief by aspirin or other prostaglandin inhibitors (positive aspirin test) (yes/no), date of diagnosis, time since symptom onset, type of therapy (radiofrequency ablation (RFA)/surgical resection), and number of MR and CT examinations before the final diagnosis was made. Furthermore, all previously suspected diagnoses that were documented in our clinical information system were collected and we assessed whether osteoid

osteoma had been one of the diagnoses. In those cases, osteoid osteoma was considered to be among the potential differential diagnoses before the first visit at our tertiary referral center. The diagnostic delay was calculated as the time interval (days) between symptom onset and first visit at our center. The time between diagnosis (first visit at our center) and treatment was also calculated in days.

Image analysis

CT and MR images were assessed by a senior expert in musculoskeletal radiology (K.W. with 27 years of experience). Regarding the location of the osteoid osteoma, the following was assessed for each patient: affected bone, location of the tumor within the bone (epi-/meta-/diaphyseal for tubular bones and posterior elements/corpus for vertebrae), location relative to cortical bone (subperiosteal/cortical/intramedullary) and relative to joints (intra-/extraarticular). The following groups were formed for analysis: tubular bones (humerus, ulna, radius, femur, tibia, fibula), small bones (all bones of the hands and feet), axial skeleton (spine and skull), pelvis, and other (clavicula, scapula, sternum). The size of the nidus was measured on CT images as the maximum diameter of the lytic lesion. The extent of reactive sclerosis was assessed as none, mild, moderate, or marked, where mild refers to slightly increased perilesional bone density, moderate refers to moderately increased perilesional bone density, and marked refers to diffuse hyperostosis. The maximum extent of bone marrow edema was measured on MR images, if available.

Statistical Analysis

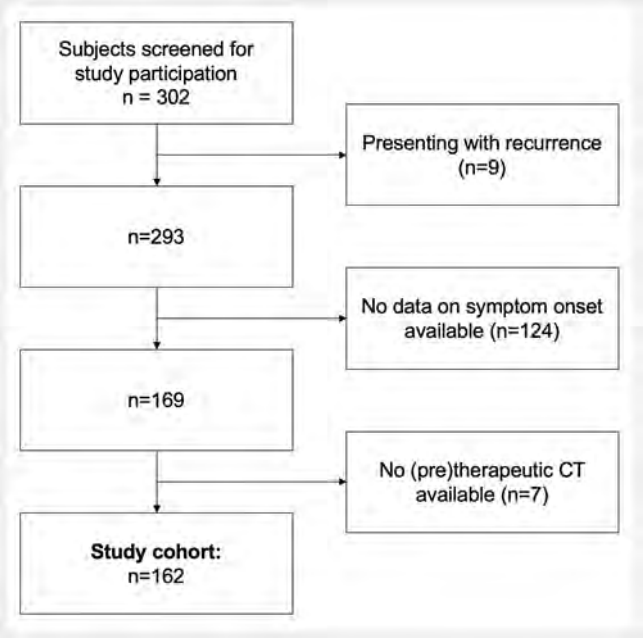
All statistical analyses were performed by F.T.G. using R version 3.2.4 (R Foundation for Statistical Computing). A P-value of less than 0.05 was considered to indicate a statistically significant difference. When statistically analyzing nocturnal pain or the aspirin test, patients were excluded if no data was available. Differences in demographics and clinical parameters for gender were analyzed using the Chi-squared test. Associations between metric parameters were assessed using Pearson's correlation coefficient. Welch's t-test was used for analyzing differences in diagnostic delay between two groups, and (Welch's) analysis of variance (ANOVA) was used for more than two groups.

Results

Demographics and clinical parameters

After all exclusions, we studied 162 patients (115 men, 47 women) with an average age of 24 ± 11 years (▶ **Table 1**).

Of all 162 patients, nocturnal pain was present in 114 patients, while it was absent in 17 patients (no data: n = 31). The aspirin test was positive in 82 patients, negative in 13 patients, and no information was available for 67 patients. 94 patients were referred to our center with differential diagnoses including osteoid osteoma, while 27 patients were referred with differential diagnoses other



▶ **Fig. 1** Flowchart illustrating subject selection.

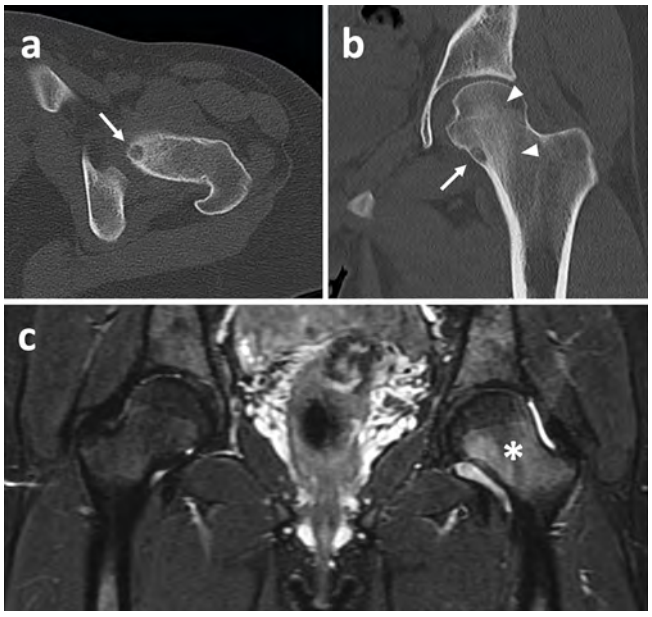
▶ **Abb. 1** Flussdiagramm zur Veranschaulichung der Patientenauswahl.

▶ **Table 1** Subject demographics and clinical parameters.

▶ **Tab. 1** Demografische und klinische Parameter.

Parameter	All	Male	Female	p-value
Patients (n)	162	115	47	
Age (y)	24 ± 11	24 ± 11	24 ± 12	p = 0.83
Nocturnal pain	114/131	80/93	34/38	p = 0.28
Positive aspirin test	82/95	62/71	20/24	p = 0.62
OO included in differential diagnoses	94/121	65/86	29/35	p = 0.76

Note – Nocturnal pain, positive aspirin test, and suspected diagnosis of osteoid osteoma are given as ratio of patients for whom the respective parameter applies and all patients for whom the respective parameter could be obtained. OO = osteoid osteoma.



▶ **Fig. 2** 15-year-old female patient with intra-articular osteoid osteoma in the left femoral neck diagnosed with a delay of 183 days. **a** Axial and **b** coronal CT reformation images clearly show a small cortical lucency (typical nidus) with central mineralization (arrow) surrounded by an area of medullary sclerosis (arrowheads). **c** Coronal T2-weighted MR image with fat suppression shows regional bone marrow edema (asterisk) and joint effusion. The nidus is, however, hardly visible.

▶ **Abb. 2** 15-jährige Patientin mit intraartikulärem Osteoidosteom im linken Schenkelhals, diagnostiziert mit einem Delay von 183 Tagen. **a** Axiale und **b** koronale CT-Reformationen zeigen deutlich eine kleine kortikale Aufhellung (typischer Nidus) mit zentraler Mineralisierung (Pfeil), umgeben von einem Bereich mit Sklerose (Pfeilspitzen). **c** Das koronale T2-gewichtete MRT-Bild mit Fettunterdrückung zeigt ein regionales Knochenmarködem (Sternchen) und einen Gelenkerguss. Der Nidus ist hier jedoch kaum sichtbar.

than osteoid osteoma, and 41 patients were referred without any suspected diagnosis.

For 17 patients, no MR examination was documented at our institution. For the remaining 145 patients, 178 documented MR examinations were found (1.23 per patient). In 5 patients, pretherapeutic CT images were not available, while 181 documented CT examinations had been performed in the remaining 157 patients (1.19 per patient). 123/162 patients had been treated by RFA, and 39/162 by surgical resection of the nidus.

Location and image assessment

▶ **Fig. 2** shows exemplary CT and MR images of a 16-year-old male patient with osteoid osteoma. Most osteoid osteomas were found in the femur (n = 62), followed by the tibia (n = 34) (▶ **Table 2**). The vast majority were located in tubular bones (n = 124). The distribution between intramedullary, cortical, and subperiosteal osteoid osteomas was equal (n = 54 each). Whereas 123 (76 %) osteoid osteomas were found in an extraarticular location, 39 (24 %) were found at intraarticular sites. Reactive bone sclerosis was absent in

▶ **Table 2** Tumor location (n = 162).

▶ **Tab. 2** Tumorlokalisation (n = 162).

Femur	62	38 %
Tibia	34	21 %
Humerus	19	12 %
Foot	12	7 %
Vertebra	11	7 %
Fibula	5	3 %
Hand	5	3 %
Radius	4	2 %
Pelvis	4	2 %
Scapula	3	2 %
Clavicula	2	1 %
Skull	1	1 %
Ulna	0	0 %
Intramedullary	54	33 %
Cortical	54	33 %
Subperiosteal	54	33 %
Extraarticular	123	76 %
Intraarticular	39	24 %

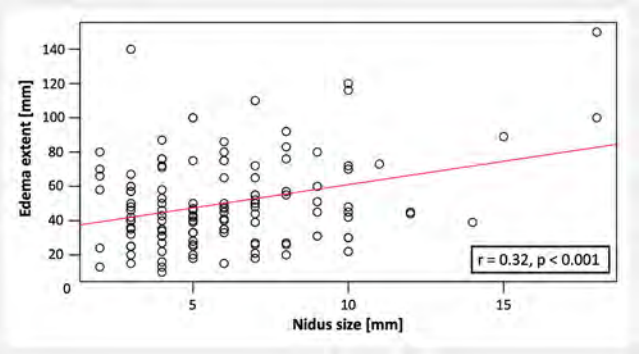
10 patients (6 %), mild in 55 patients (34 %), moderate in 57 patients (35 %), and marked in 40 patients (25 %).

The average nidus size was 6.0 ± 3.0 mm. The average maximum extent of bone marrow edema was 50.0 ± 26.3 mm. We found a positive correlation between nidus size on CT and extent of bone marrow edema on MR imaging ($r = 0.32$, $p < 0.001$) (▶ **Fig. 3**).

Diagnostic delay

The average diagnostic delay was 419 ± 485 days (median: 275 days; range: 21–4503 days). The longest diagnostic delay was found in a 25-year-old male patient with an osteoid osteoma in the proximal left humerus. No difference was found between men (445 ± 531 days) and women (353 ± 343 days; $p = 0.19$) (▶ **Fig. 4**). Also, no correlation was found between diagnostic delay and patient age ($p = 0.82$). The delay was, however, longer for patients who were referred to our institution with differential diagnoses not including osteoid osteoma (587 ± 463 days) compared to those with differential diagnoses including osteoid osteoma (318 ± 291; $p = 0.007$). No differences in diagnostic delay were found for the presence/absence of nocturnal pain (present: 413 ± 519, absent: 411 ± 383; $p = 0.98$) or responsiveness to analgesics (positive aspirin test: 408 ± 358 days, negative aspirin test: 334 ± 379 days; $p = 0.49$).

With respect to tumor location, the diagnostic delay was shorter with affection of long tubular bones (376 ± 485 days) compared to all other skeletal sites (560 ± 462 days, $p = 0.04$). However, when comparing all subgroups (long tubular bones, small bones of hands and feet, axial skeleton, pelvis, other), no significant



▶ **Fig. 3** Comparison of nidus size and edema extent. Edema extent was positively correlated with nidus size (r = 0.32, p < 0.001). Red line indicates regression line of the linear model using the least squares method.

▶ **Abb. 3** Vergleich von Nidusgröße und Ödemausdehnung. Die Ausprägung des Ödems korrelierte positiv mit der Nidusgröße (r = 0,32, p < 0,001). Die rote Linie zeigt die Regressionslinie des linearen Modells unter Verwendung der Methode der kleinsten Quadrate an.

differences were found in diagnostic delay (p = 0.09). Also, no differences were found regarding the location of the lesion relative to cortical bone (p = 0.28) and joints (p = 0.35).

The diagnostic delay was positively correlated with nidus size (r = 0.26; p < 0.001), but it did not show dependence on the extent of reactive sclerosis (p = 0.78) or extent of bone marrow edema (p = 0.71).

The average time span between final diagnosis of osteoid osteoma at our institution and treatment by RFA or surgery was 33 ± 31 days.

Discussion

In this study, we evaluated diagnostic delay in patients with osteoid osteoma and the number of associated imaging procedures as well as the influence of various clinical parameters and imaging findings on the time from symptom onset to final diagnosis. The average diagnostic delay was 419 ± 485 days (median: 275 days; range: 21–4503 days). Gender, patient age, presence of nocturnal pain, positive aspirin test, extent of bone sclerosis, and location of the tumor within bone and relative to joints did not influence diagnostic delay (p > 0.05). It was, however, positively correlated with nidus size (r = 0.26; p < 0.001) and was shorter with affection of long tubular bones compared to all other sites (p = 0.04). If osteoid osteoma was included in the initial differential diagnoses, the diagnostic delay was also shorter (p = 0.007).

Regarding the pathophysiology of osteoid osteoma, prostaglandin E2 and prostacyclin production has been found within the nidus, which is believed to cause local inflammation, resulting in bone and soft tissue edema. Furthermore, high levels of cyclooxygenase-2 expression in the nidus are believed to be the reason for the relief of symptoms upon cyclooxygenase-2 inhibition [11]. These inflammatory mediators may also contribute to perilesional bone sclerosis exhibited by most osteoid osteomas. In addition, high concentrations of intralesional unmyelinated nerve fibers have been implicated in the pathogenesis of the nocturnal pain. It is probable that these function in parallel to produce the characteristic inflammatory symptoms [12–14].

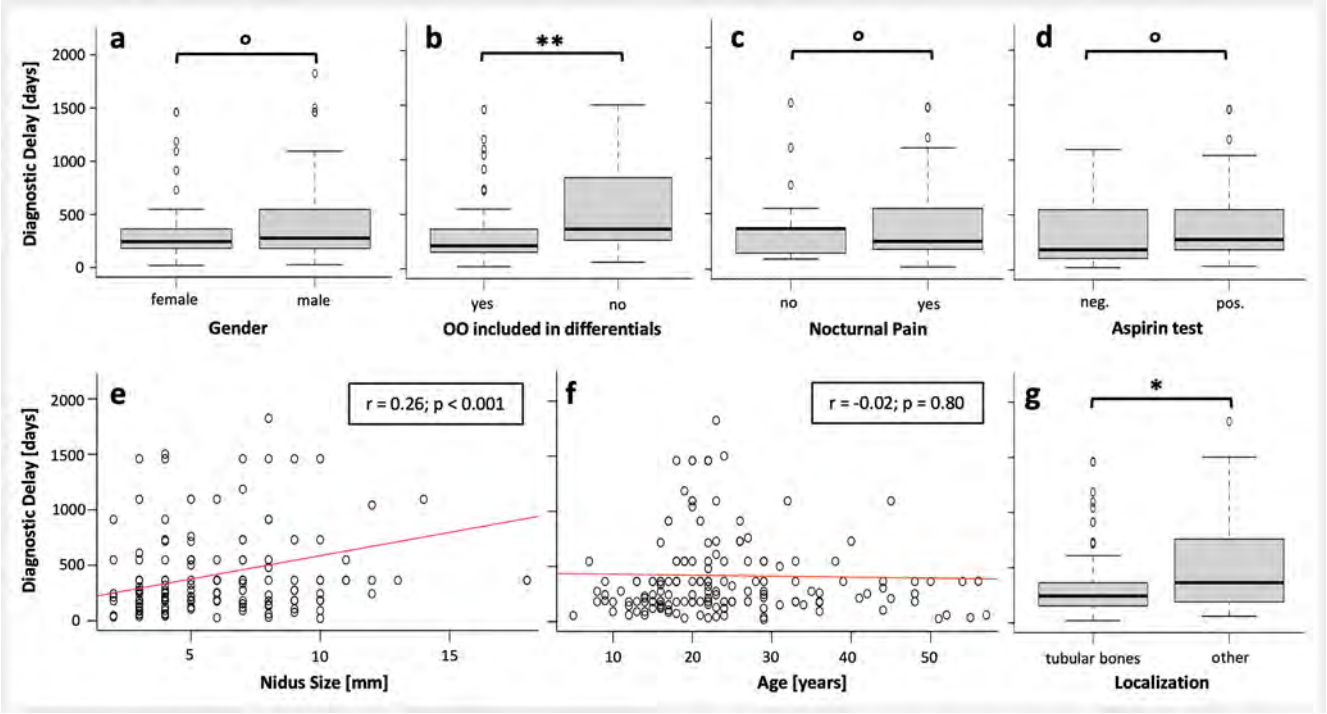
While the pathophysiology of osteoid osteoma remains controversial, imaging features have been well investigated. Considering that cross-sectional imaging is widely available in developed countries, and that CT findings are fairly pathognomonic, an average diagnostic delay of more than one year appears unacceptably long for a disease as common as osteoid osteoma [7, 15–17]. Furthermore, atraumatic bone marrow edema observed on MR imaging in a young patient with chronic pain, often more severe at night, represents a typical scenario which should alert physicians to this diagnosis.

Our study results are well within range of previous studies regarding mean age and male predominance as well as involvement of long tubular bones [15, 18, 19]. While previous studies reported predominantly subperiosteal and intracortical locations [15, 20], we found an equal distribution for subperiosteal, intracortical and intramedullary locations.

The diagnostic delay has only been sparsely investigated so far. Our results are well in line with a study by Klein et al. who reported a mean pain duration of 15.6 months in a cohort of 48 patients with osteoid osteoma [19], suggesting a low awareness of the disease. Another study by Touraine et al. assessed pain duration calculated as the time between the estimated date of the onset of pain and the date of treatment [10]. They observed a median pain duration of 13 months, which is well within the range of our results (diagnostic delay: median: 275 days), considering that our approach used the date of diagnosis instead of the date of treatment. Similar to our results, they did not find differences in pain duration regarding the location of osteoid osteoma relative to cortical bone and bone segments involved. While another study by Kaiser et al. [20] reported a significant correlation of pain duration with age, we found no correlation between diagnostic delay and age. The positive correlation between diagnostic delay and nidus size in our study is contradictory to the results of Touraine et al. and also surprising as previous observations have suggested that osteoid osteomas lack growth potential [21, 22].

While it is well known that both the presence of nocturnal pain and the relief by aspirin or other prostaglandin inhibitors (positive aspirin test) are characteristic for osteoid osteoma [15, 23], we did not find a longer diagnostic delay in patients without those characteristics. The observation that the diagnostic delay was shorter if long tubular bones were affected is not surprising and may be due to the fact that osteoid osteomas are more expected and easier to diagnose at such sites. Also, a shorter diagnostic delay in patients for whom osteoid osteoma had already been suggested as a possible diagnosis was to be expected. Nevertheless, in our study, no specific reason for the long diagnostic delay of more than one year could be identified, suggesting low awareness of the disease.

Osteoid osteoma is diagnosed by a combination of typical clinical features and imaging findings. Clinical findings include local pain, which is often more severe at night and can be relieved by aspirin or other prostaglandin inhibitors, typically seen in children and young adults. Imaging findings include a hypodense nidus on CT with surrounding reactive sclerosis of variable extent as well as ad-



▶ **Fig. 4** Comparison of demographics, clinical, and imaging parameters with diagnostic delay. Gender (p = 0.19) (**a**), nocturnal pain (p = 0.98) (**c**), a positive Aspirin test (p = 0.49) (**d**), and patient age (**f**) did not influence diagnostic delay. Diagnostic delay was shorter in patients in whom osteoid osteoma had previously been among differential diagnoses (p = 0.007) (**b**). Diagnostic delay correlated positively with nidus size (**e**). Also, diagnostic delay was shorter, if long tubular bones were affected compared to all other sites (p = 0.04) (**c**). Note: For one case the diagnostic delay was 4503 days. This case was excluded from graphs for better visibility but was included in all analyses. Symbols indicate significance levels for each respective test: °: p > 0.05, * = p < 0.05, **: p < 0.01.

▶ **Abb. 4** Vergleich demografischer, klinischer und bildgebender Parameter mit dem diagnostischen Delay. Geschlecht (p = 0,19) (**a**), nächtliche Schmerzen (p = 0,98) (**c**), ein positiver Aspirin-Test (p = 0,49) (**d**) und das Alter des Patienten (**f**) hatten keinen Einfluss auf den diagnostischen Delay. Er war kürzer bei Patienten, bei denen zuvor ein Osteoidosteom zu den Differenzialdiagnosen zählte (p = 0,007) (**b**). Der diagnostische Delay korrelierte positiv mit der Nidusgröße (**e**). Außerdem war er kürzer, wenn lange Röhrenknochen im Vergleich zu allen anderen Lokalisationen betroffen waren (p = 0,04) (**c**). Hinweis: In einem Fall betrug der diagnostische Delay 4503 Tage. Dieser Fall wurde zur besseren Übersichtlichkeit aus den Diagrammen ausgeschlossen, jedoch in alle Analysen einbezogen. Symbole geben Signifikanzniveaus für den jeweiligen Test an: °: p > 0,05, * = p < 0,05, **: p < 0,01.

jacent bone marrow edema on MR imaging. Osteoid osteoma is most commonly seen in the long tubular bones but can affect virtually every part of the skeleton. The most common cause of diagnostic delay in patients with osteoid osteoma is probably the initial use of MR imaging, which may only show localized bone marrow edema. In young patients, bone marrow edema is almost always a secondary phenomenon, and thus, should alert the radiologist to search for underlying causes, such as stress fracture, infection, or osteoid osteoma. This is ideally done by adding CT. Particularly if located at unusual sites, osteoid osteoma might, however, be difficult to diagnose or exhibit atypical findings. Therefore, early consultation with an expert in the field or the referral to a specialized musculoskeletal center can be of great help.

Osteoid osteoma (OO) typically follows a natural course of spontaneous regression within 6 to 15 years. However, this timeframe can be notably shortened to 2 to 3 years by continuous application of nonsteroidal anti-inflammatory drugs (NSAIDs) [24]. Despite the availability of pharmacological treatment as an option, its utilization is limited due to the adverse effects associated with prolonged NSAID use, such as the risk of bleeding complications and gastric and renal toxicity [25]. Therefore, pharmacological treatment is nowadays reserved for exceptional cases. More commonly employed treatment approaches encompass surgical resection, which is associated with a considerable degree of morbidity and a lengthy recovery period, and percutaneous imaging-guided treatment, particularly radiofrequency ablation and laser photocoagulation, which boast a clinical success rate exceeding 90 % [26, 27] as well as MR imaging-guided high-intensity focused ultrasound, which has been proven to be a safe and radiation-free alternative to the previous method while yielding similar results [28, 29].

We acknowledge several limitations to this study. In this retrospective analysis, all documented CT and MR imaging examinations were counted resulting in an average of 1.23 MR and 1.19 CT examinations per patient. However, we assume that this is the absolute minimum and that actual numbers are (much) higher, as repetitive imaging is often performed in unclear cases. This was, however, not always documented in our clinical information system. The observation that no (pretherapeutic) CT examination was documented in our system for 5 patients and no MR

examination was documented in our system for 17 patients supports this assumption, as it is highly unlikely that imaging was not actually performed on those patients. Also, we acknowledge that the assessment of the osteoid osteoma location in relation to cortical bone may be difficult in flat or small bones, given the thin cortices and the difficulty differentiating subperiosteal from intracortical osteoid osteoma. It is suggested that this could lead to an overestimation of the proportion of intracortical osteoid osteoma [10]. Another limitation is the fact that the time between symptom onset and initial imaging as well as the time between initial imaging and diagnosis could not be assessed. Finally, it needs to be mentioned that this is a single-center study conducted in one European country. Thus, local conditions such as medical education of health care providers, availability of advanced imaging, and other healthcare system-specific factors might have influenced our results.

In conclusion, the diagnostic delay in patients with osteoid osteoma is independent of demographics, clinical parameters, and most imaging parameters. A long average delay of more than one year suggests low awareness of the disease among physicians. Thus, patients with unclear imaging findings should be referred to a specialized musculoskeletal center or an expert in the field should be consulted in a timely manner.

Conflict of Interest

The authors declare that they have no conflict of interest.

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