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Magnetic resonance imaging features for the differential diagnosis of local recurrence of bone sarcoma after prosthesis replacement

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Abstract    Objective: To explore the imaging features of local recurrences (LRs) based on magnetic resonance imaging (MRI) after oncological orthopaedic surgery with prosthesis reconstruction.
Methods: A total of 78 cases totalling 157 scans were retrospectively reviewed. Patients with nodule/mass-like signals were retrospectively classified into LR, infectious pseudotumour, and asymptomatic pseudotumour according to clinicopathological data. LRs were histologically confirmed, and the patients without recurrences were followed up for at least 2 years. Mass size distribution and radiological characteristics were analysed for differential diagnosis of the LR versus pseudotumour.
Results: Thirty-three of 78 cases were positive with nodule/mass-like signal findings on the post-operative MRI images. By analysing the size distribution, we found that masses >2.1 cm (14) were almost attributable (98% specificity) to LRs and mostly (84.6%) timely treated. Contrarily, masses ≤2.1 cm (19) are challenging for differential diagnosis of LRs versus pseudotumour and were undertreated in five of the nine LR cases. MRI characteristics of masses ≤2.1 cm were found to be highly heterogeneous, with solid appearance, adjacent infiltration,
Introduction

To date, there are no universally accepted protocols for the radiological surveillance of local recurrences (LRs) after oncological prosthetic reconstruction surgery of the limb. For this reason, X-ray, computed tomography, and ultrasound used to play an important role in the detection of complications and pathologic conditions post-operatively. However, X-ray or computed tomography is less sensitive in demonstrating lesions in the deep soft tissue with potential ionising radiation hazard [1,2], while ultrasound still suffers from high degree of interoperator variability and inter-reader subjectivity [3]. Owing to its superior soft tissue contrast, magnetic resonance imaging (MRI) is theoretically a preferable modality after oncological orthopaedic surgery with prosthetic reconstruction as it is reported previously that most of the LRs occur within soft tissue rather than bone stumps for bone sarcoma such as osteosarcoma [4]. But its clinical use of imaging around prosthesis was historically limited by metal-induced artifacts. With the advent of metal artifact reduction sequence, MRI is now regaining wider popularity for post-operative follow-up with a metal implant [5-7]. Some authors have reported that optimized MRI parameters with higher bandwidth and view angle tilting (VAT) had diminished imaging metal artifact and better image quality requiring no more additional devices and scanning time compared with conventional MRI parameters [8]. A higher receiver bandwidth which attempts to orient the frequency-encoding direction along the long axis of the prosthesis can be able to decrease the voxel size, while VAT is developed to correct in-plane distortion [7,9]. These cost-effective techniques are now routinely applied in our hospital for follow-ups of patients with bone sarcoma after prosthetic replacement.

Furthermore, small size and resectability of recurrent tumours detected before resurgery are well known to be associated with better prognosis for LRs of osteosarcoma [10,11]. For this reason, accurate interpretation of post-operative radiological signs indicating LRs and complications such as pseudotumour, infection, haematoma, and scar formation in these patients contributes a lot to further management. It is noteworthy that pseudotumours are predominately reported after metal-to-metal joint arthroplasty on MRI with unclear incidence and radiological manifestations after bone tumour prosthesis placement [12-14]. The difficulty of interpreting such radiological results can be further complicated by periprosthetic imaging artifact (signal loss and distortion) and other periprosthetic abnormalities (periprosthetic effusion, oedema, and so forth.). There is no denying that the radiological differentiation between true LR versus pseudotumour condition is remarkably critical because their clinical trajectories and decision-making are drastically different. However, data regarding such issue of MRI are still lacking in the current literature. In addition, gadolinium-enhanced MRI was traditionally believed as a favourable choice for diagnosis of recurrence, but nonenhanced MRI was of low cost and more time saving which had potential to be a preferred choice for initial evaluation of suspicious patients in clinical settings.

The study objectives were to investigate whether non-enhanced MRI was feasible to detect the early signs of LRs, differentiate pathologic conditions from normal post-operative conditions, and indicate further management. To our knowledge, there were rare reports about the post-operative imaging manifestations in patients with bone malignant tumour with prosthesis by MRI [8,15].

Materials and methods

Study group and radiological evaluation

With an institutional review board approval for retrospective data analysis and a waiver of the requirement for informed consent, a cross-sectional study from January 2014 to March 2018 was conducted to examine the post-operative MRI images of patients with pathology-proven bone or soft tissue sarcoma. The inclusion criterions were the following: (1) patients who have undergone resection of the tumour segment and prosthesis replacement. All materials for prosthesis were cobalt-chromium-molybdenum alloy; (2) MRI was performed owing to clinical presentations or suspicious radiological manifestations such as abnormal oedema, swelling, and dubious mass signal from our hospital and other institutions; (3) MRI image quality met the...
needs of diagnosis; (4) further management or examinations were carried out when suspecting recurrent tumours; and (5) at least 24 months of clinical follow-up in non-recurrent patients. The exclusion criteria were the following: (1) patients were lost during the follow-up; (2) new injury to the ipsilateral limb. MRI was performed on 1.5-T Aera unit (Siemens, Erlangen, Germany) with an eight-channel body coil. High bandwidth and VAT technique were adopted to metal-induced artifacts. MRI sequences included the following: coronal T1-weighted imaging (T1WI), coronal short time inversion recovery (STIR), coronal T2-weighted imaging (T2WI), transverse T2WI, and transverse STIR. Detailed parameters of upper extremity, hip, and lower extremity were listed in Table 1.

For a standardized evaluation of post-operative MRI images, the following radiological features were examined: (1) nodule/mass-like signal: 0, absent; 1, present. Detailed descriptions were in the following additional evaluation; (2) muscular oedema: 0, weak or absent; 1, focal or peritumour oedema; 2, diffuse oedema. Muscular oedema was defined as regional low signal intensity on T1WI and high signal intensity on T2WI and STIR in muscle; (3) scar tissue: 0, absent; 1, present; characterized by stranded low signal intensity on all sequences; (4) lymphadenopathy: 0, absent; 1, <1 cm; 2, >1 cm; demonstrated as oval shaped low-intermediate signal intensity on T1WI and intermediate–high signal intensity on T2WI and STIR; (5) subcutaneous tissue oedema: 0, absent; 1, present, which was defined as patchy of diffuse low signal intensity on T1WI and high signal intensity on T2WI and STIR; (6) synovitis: 0, absent; 1, present, which was shown as massive synovial proliferation in "lamellated" or multilayered fashion within effusion, with low–intermediate signal intensity on T1WI and intermediate–high signal intensity on T2WI and STIR [16,17]; (7) periprosthesys fluid: 0, absent; 1, present; (8) osseous oedema: 0, absent; 1, present, which was demonstrated as low signal intensity on T1WI and high signal intensity on T2WI and STIR with ill-defined border on the bone structure; (9) haematoma: 0, absent; 1, present, which was demonstrated as mixed high signal intensity on T1WI and variable signal intensity on T2WI and STIR with fluid levels [18]; and (10) osteolysis: 0, absent; 1, present, which was shown as expansive and infiltrative low signal intensity on T1WI and high signal intensity on T2WI and STIR with low signal intensity rim on all sequences [19].

As mentioned previously, when the presence of nodule/mass-like signal was identified, additional parameters were also evaluated as follows: (1) cystic versus solid: 0, solid or mixed solid; 1, entirely cystic; solid mass was defined as intermediate–low signal intensity on T1WI and inhomogeneous intermediate-to-high signal intensity on T2WI and STIR [6]. Cystic mass was defined as low signal intensity on T1WI and very T2WI and STIR hyperintense signal; (2) mass count: 0, one; 1, more than one; (3) mass shape: 0, round; 1, irregular; (4) mass border: 0, well defined; 1, ill defined; and (5) adjacent tissue infiltration: 0, absent; 1, present [20,21]. Only the largest solid or cystic mass was evaluated if multiple masses existed on single MRI image.

Radiological features of all MRI images were independently evaluated by two radiologists both with more than 5 years of experience in musculoskeletal imaging who were blinded to the clinical and pathological diagnosis. When their initial description of imaging signs were dissented, a third senior radiologist with more than 10 years of experience in musculoskeletal imaging was resorted to determine the radiological signs. Their evaluation was subsequently compared with pathological and clinical results. These results were in accordance with the following rules: (1) all diagnoses of LRs were confirmed by pathological examinations; (2) diagnosis of pseudotumours was confirmed by pathological examination or radiological follow-up of minimum of 24 months; (3) infection was determined by surgery and laboratory examinations; and (4) other abnormalities were estimated by radiological follow-up of at least 24 months.

### Statistical methods

Numeric data and scores were expressed as mean (range). The sensitivity and specificity curve with Youden’s J statistics was used to determine the decision threshold of the tumour size in diagnosing LRs. Principal component analysis (PCA) was used to generalize the imaging features of the nodule/mass-like signal. In addition, univariate and multivariate logistic regression analyses were used to determine the significant radiological features associated with LRs. A

| Sequence/parameters | Coronal T1WI | Coronal T2WI | Coronal STIR | Transverse T2WI | Transverse STIR |
|---------------------|-------------|-------------|-------------|----------------|----------------|
| TR/TE (mm)          | 416/13      | 5660/110    | 4060/37     | 5660/110       | 10,580/70      |
| FoV (mm)            | 403         | 500         | 400         | 280            | 180            |
| Averages            | 2           | 2           | 2           | 2              | 2              |
| Slice thickness (mm)| 3.0         | 3.0         | 3.0         | 3.0            | 5.0            |
| Slices              | 24          | 28          | 24          | 40             | 39             |
| Voxel size (mm)     | 1.3 × 1.3 × 3.0 | 1.3 × 1.3 × 3.0 | 1.3 × 1.3 × 3.0 | 0.7 × 0.7 × 3.0 | 0.6 × 0.6 × 5.0 |
| Matrix              | 232 × 384   | 271 × 384   | 195 × 320   | 209 × 384      | 189 × 320      |
| Bandwidth (Hz/Px)   | 334         | 434         | 391         | 434            | 434            |
| VAT                 | /           | 50%         | 50%         | 50%            | 50%            |
| Echo trains         | /           | 15          | 26          | 10             | 14             |
| Flip angle          | 90°         | 150°        | 150°        | 150°           | 150°           |

MRI = magnetic resonance imaging; TR = repetition time; TE = echo time; FoV = field of view; VAT = view angle tilting; T1WI = T1-weighted imaging; T2WI = T2-weighted imaging; STIR = short time inversion recovery.
receiver operating characteristic curve was used to evaluate this predictive model. Statistical analysis was performed using Analyse-it 4.51 and Statistical Product and Service Solutions 22.0 statistical software. *P* value of 0.05 was chosen as the threshold considered significant.

**Results**

**Clinicopathological characteristics and MRI features**

A total of 78 patients (52 males and 26 females) were included in our study with a mean age of 26.0 ± 13.8 years (7–65 years old). There were 59 osteosarcomas, including 54 conventional and five nonconventional osteosarcomas (four osteosarcomas secondary to giant-cell tumour and one osteosarcoma secondary to fibrous dysplasia), six Ewing’s sarcomas, four chondrosarcomas, and seven polymorphic undifferentiated sarcomas. The remaining two cases were rhabdomyosarcoma and epithelioid angiosarcoma, which involved massive bone destruction and required prosthetic reconstruction. Affected sites included distal femur (35/78), proximal tibia (13/78), proximal femur (11/78), proximal humerus (8/78), pelvis (5/78), proximal fibula (2/78), distal humerus (2/78), distal tibia (1/78), and proximal ulna (1/78).

Among these 78 patients, nodule/mass-like signals were found in 33 patients, with 26 appearing as solid or mixed solid and seven as cystic. LRs were later proven by pathology in 22 patients (42 MR scans, with 31 scans showing masses, 18 males and four females, mean age 27.5 ± 12.5 years, range 9–52 years) with a median follow-up time of 18.6 ± 14.3 months (3–55 months) (Fig. 1A). Fifteen patients had osteosarcoma, three had Ewing’s sarcoma, three had chondrosarcoma, and one had polymorphic undifferentiated sarcoma. After the initial emergence of masses on MRI, 13 patients (59.1%) underwent surgery within 1 month (mean tumour size 5.8 ± 4.3 cm, range 1.8–16 cm), seven patients (31.8%) were continually followed up by MRI showing progressing large masses and finally underwent surgery (mean tumour size of the last MRI 6.8 ± 4.9 cm, range 2.8–16 cm), and for the remaining two patients (9.1%), needle biopsy was performed to confirm recurrences (tumour size 1.1 and 1.8 cm, respectively).

Of the remaining 11 pseudotumour cases (19 MR scans), eight pseudotumours were shown to be unchanged or regressed through the course of follow-up (at least 24 months), with needle biopsy confirmed as benign reactive changes in two of them. For the other three patients, one presented with signs and symptoms suspected of infection, and two of them showed progressive manifestations of periprosthetic infection within the next month, with

**Table 2** Hip MRI sequence parameters for MRI.

| Sequence/parameters | Coronal T1WI | Coronal T2WI | Coronal STIR | Transverse T2WI | Transverse STIR |
|---------------------|--------------|--------------|--------------|----------------|----------------|
| TR/TE (mm)          | 446/6.4      | 5660/110     | 4510/37      | 4660/71        | 9020/37        |
| FoV (mm)            | 500          | 500          | 500          | 444            | 500            |
| Averages            | 2            | 2            | 2            | 2              | 2              |
| Slice thickness (mm)| 3.0          | 3.0          | 3.0          | 4.0            | 4.0            |
| Slices              | 24           | 24           | 24           | 36             | 30             |
| Voxel size (mm)     | 1.0 × 1.0 × 3.0 | 1.3 × 1.3 × 3.0 | 1.6 × 1.6 × 3.0 | 0.9 × 0.9 × 4.0 | 1.6 × 1.6 × 4.0 |
| Matrix              | 512 × 512    | 282 × 384    | 280 × 320    | 252 × 512      | 180 × 320      |
| Bandwidth (Hz/Px)   | 751          | 434          | 601          | 610            | 601            |
| VAT                 | 50%          | 50%          | 50%          | 50%            | 50%            |
| Echo trains         | 86           | 13           | 17           | 9              | 11             |
| Flip angle          | 150°         | 150°         | 150°         | 150°           | 150°           |

TR = repetition time; TE = echo time; FoV = field of view; VAT = view angle tilting; MRI = magnetic resonance imaging; T1WI = T1-weighted imaging; T2WI = T2-weighted imaging; STIR = short time inversion recovery.

**Table 3** Knee MRI sequence parameters for MRI.

| Sequence/parameters | Coronal T1WI | Coronal T2WI | Coronal STIR | Transverse T2WI | Transverse STIR |
|---------------------|--------------|--------------|--------------|----------------|----------------|
| TR/TE (mm)          | 416/13       | 5660/110     | 5660/37      | 5660/114       | 10,580/70      |
| FoV (mm)            | 500          | 500          | 500          | 200            | 200            |
| Averages            | 2            | 2            | 2            | 2              | 2              |
| Slice thickness (mm)| 3.0          | 3.0          | 3.0          | 5.0            | 5.0            |
| Slices              | 24           | 24           | 24           | 25             | 39             |
| Voxel size (mm)     | 1.3 × 1.3 × 3.0 | 1.3 × 1.3 × 3.0 | 1.6 × 1.6 × 3.0 | 0.5 × 0.5 × 5.0 | 0.6 × 0.6 × 5.0 |
| Matrix              | 285 × 384    | 282 × 384    | 203 × 320    | 282 × 384      | 182 × 320      |
| Bandwidth (Hz/Px)   | 334          | 434          | 391          | 434            | 434            |
| VAT                 | /            | /            | /            | /              | /              |
| Echo trains         | /            | /            | /            | /              | /              |
| Flip angle          | 90°          | 150°         | 150°         | 150°           | 150°           |

TR = repetition time; TE = echo time; FoV = field of view; VAT = view angle tilting; MRI = magnetic resonance imaging; T1WI = T1-weighted imaging; T2WI = T2-weighted imaging; STIR = short time inversion recovery.
further evidence proving these pseudotumours as infectious origins.

Among 45 cases without nodule/mass-like signals (89 scans), muscle oedema was found in 65 images, scar tissue in 60 scans, lymphadenopathy less than 1 cm in eight scans, periprostheses fluid in all 89 scans, osseous oedema in five images, no haematoma, synovitis in eight scans and subcutaneous oedema in 31 scans.

Differentiation of small-sized mass on MRI images

Because the large-sized mass found on the MRI image was the most intuitive diagnostic consideration of LRs, we first looked at the relationship between the mass size and mass diagnosis (Fig. 1B). Our result confirmed that LRs tended to be larger and commonly exhibited as solid appearance, while pseudotumours were smaller and mostly cystic. To reach a potential decision threshold, the sensitivity and specificity of various mass sizes for a radiological diagnosis were analysed (Fig. 1C). Youden’s J statistics suggested a cut-off value of 2.1 cm had highest diagnostic efficiency for LRs, with a limited sensitivity of 77.4% (95% CI 58.9–90.4) but a high specificity of 98.21% (95% CI 93.7–99.8%), indicating that masses greater than 2.1 cm on MRI images were almost attributable to LR of the malignancy. OSA = osteosarcoma; MRI = magnetic resonance imaging; LRs = local recurrences.

Figure 1  Size of (pseudo)tumours found on post-operative MRI images after oncological prosthetic reconstruction of extremities. (A) Pathological composition of the primary tumour undergoing MRI in our study. (B) The size distribution of solid masses and cystic mass on MRI images at the scan level. LRs mainly presented as large-sized solid or mixed solid masses, while pseudotumours, as small-sized cystic masses in appearance. (C) By comparing various cut-off values, a mass size of 2.1 cm was chosen with highest Youden’s J statistics (77.4 sensitivity, 98.21% specificity), indicating that masses greater than 2.1 cm on MRI images were almost attributable to LR of the malignancy. OSA = osteosarcoma; MRI = magnetic resonance imaging; LRs = local recurrences.
follow-up. In 13 patients with LRs where the initial findings of LRs were greater than 2.1 cm, 11 of 13 were further proceeded to either biopsy or surgery. Strikingly, for the remaining nine patients with LRs, only four of the nine small masses (≤2.1 cm) were timely intervened, with the rest five cases given observation for another 2–3 months, potentially missing the optimal therapeutic timing. These results suggested that the early radiological diagnosis of small LRs was challenging yet worthy of further investigation.

Heterogeneous appearance of small-sized LRs on MR images

To summarize the general features for images with small masses (≤2.1 cm) in appearance, we performed PCA to extract common patterns for LRs and pseudotumour conditions (infection and asymptomatic pseudotumours) (Fig. 2). A scree plot demonstrated that the majority (63.4%) of variance of the MRI image characteristics (excluding the periprostheses fluid, osseous oedema and haematoma due to their extreme low variance) could be explained by the first two principal components (PCs), namely PC1 (35.5%) and PC2 (27.9%) that had the two largest possible variances. As shown in Fig. 2, the radiological appearance of LRs varied tremendously across features, with solid, infiltrative appearance with little scarring or surrounding muscular oedema as its most common manifestation (Fig. 3A and B). Our results also showed that the imaging features of LR mass with a small size could be atypical and may be misinterpreted when mimicking asymptomatic pseudotumour (Fig. 4 and Fig. 5). Infectious pseudotumours and, to a lesser extent, asymptomatic pseudotumours were clustered according to their imaging features on PCA. For example, infectious pseudotumours were typically multifocal, with synovitis at the adjacent joint and commonly occurred at the later stage (11 months, 38 months, and 65 months, in our series) (Fig. 3C and D), while asymptomatic pseudotumours commonly presented as clear-bordered, round-shaped, cystic masses (Fig. 5C and D).

Differential diagnosis of LRs for small-sized masses on MR images

To identify the radiological features differentiating LRs from pseudotumour, we performed logistic regression analysis for MRI images with ≤2.1 cm masses during post-operative follow-ups. Solid mass, adjacent infiltration, and less surrounding muscular oedema tended to be indicative of recurrent malignancies, while the opposite tended to be indicative of pseudotumour ($P < 0.05$) (Table 4). Interestingly, the predictive model using such three variables yielded an area under curve (AUC) of 0.93 as shown by receiver operating characteristic curve analysis (Fig. 6).

PCA = principal component analysis; MRI = magnetic resonance imaging; LRs = local recurrences.
performance of LRs. However, our results suggested that none of these MRI findings were significant indicators associated with LRs ($P > 0.05$, some detailed data were not shown).

**Discussion**

The most significant findings of our study were that for routine follow-ups in patients with bone sarcomas after prosthesis surgery, MRI could also detect tumours, demonstrate the early signs of LRs, and identify benign lesions.

Because small size and resectability of recurrent tumours were reported to be favourable prognostic factors for bone malignancies such as osteosarcoma, promptly identifying recurrent malignancies could not only increase the limb salvage rate but also potentially improve overall patient survival [10,11]. Consistent with the previous reports, we have observed a high incidence of pseudotumour (11 of 78) on MRI images, which demanded further endeavours to make differential diagnosis [22,23]. Our study found some useful signs and manifestations to evaluate post-operative noncontrast MRI images in these patients to help orthopaedists to decide the next step, which consist of routine follow-up, further examination, alteration of chemotherapy treatment, needle biopsy, and surgery.

In our analysis, we found that the mass displayed on the MRI image, whenever its size exceeded 2.1 cm, should prompt responsible clinicians to consider tumour recurrence. Besides, for the early detected small mass on MRI that is not greater than 2.1 cm, three characteristics are significant for the radiological differential diagnosis of LRs. One is the presence of localized intermediate-to-high T2WI

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**Figure 3** Typical signs of recurrent tumours and infection on MRI images. (A) Local recurrence (arrowhead) of osteosarcoma in the right proximal femur was found anterior to the femur prosthesis (upper). On transverse T2WI image, the mass was presented as intermediate-to-high signal intensity with infiltration to the adjacent muscle and fat tissue. The malignancy was resistant to chemotherapy and progressively invaded into the adjacent tissue (lower). (B) A small-sized mass in the left humerus was detected close to the distal humerus prosthesis. Coronal T2WI image showed a solid mass in intimate relation with adjacent muscle without obvious peritumour oedema. Re-resection of the lesion proved it to be recurrent Ewing’s sarcoma. (C, D) A 22-year-old male complained of mild knee pain 38 months after osteosarcoma resection and prosthetic reconstruction in the left distal femur. Coronal T2WI MRI showed cystic masses (arrowhead) accompanied by "lamellated" synovitis, which was later diagnosed to be periprosthetic infection.

MRI = magnetic resonance imaging; T2WI = T2-weighted imaging.
or STIR signal intensity, representing solid or mixed solid masses in the muscle and adipose space. In our study, solid or mixed solid masses were found in all except one patient with LRs, while six of 11 pseudotumours are cystic. This result was in parallel with the previous literature, suggesting solid pseudotumours were uncommon [24]. The other two features are adjacent tissue infiltration and less surrounding muscular oedema. In other words, a small LR tends to appear invasive, but with little muscular oedema probably because its size is too limited to evoke extensive muscular oedema. However, our PCA analysis demonstrated that the MRI appearance of LRs was more heterogeneous than that of benign pseudotumour, indicating the difficulty of generalising all LRs into a stereotypical pattern. In our opinion, whenever an ambiguously appearing mass with any one of these features is seen during the MRI follow-up, awareness should be raised, and further examinations such as enhanced MRI and other modalities might be needed before definitive diagnosis.

Noninfectious pseudotumour has been associated with aseptic inflammation, or necrotic tissue, and could sometimes be progressive according to literature [25]. However, in our study, the only three progressive pseudotumours were associated with infectious origin, with the same incidence as the previous report by Aponte-Tinao et al. (5.7%) [26]. We felt that critical clues to infection included extensive deep soft tissue swelling, sinus tract, considerable synovitis, and accompanied small solid masses representing abscesses. The more the signs appear, the higher the likelihood of infection is. Synovitis could appear as either "lamellated" or multilayered fashion, which has been proved to be, especially, a high sensitive and specific sign for diagnosing infection [17].

For the remaining eight asymptomatic pseudotumours, our data suggested that these masses were nonprogressive and required no specific intervention, at least within the afterward 2 years. Recent studies have demonstrated that pseudotumours were frequent findings without associations with the prosthesis position and wear [27]. In patients who underwent total hip arthroplasties, cystic lesions around prosthesis, accounting for most pseudotumours, were normal findings without significant correlation to poor

Figure 4  Solid pseudotumour mimicking local recurrence. A small-sized recurrent osteosarcoma in the left proximal humerus was shown on coronal T2WI (A) and transverse STIR (B) MRI images, as an infiltrative mixed solid mass (arrowhead). Haematoma was seen posterior to the mass. (C, D): A 42-year-old female underwent tumour resection on the left distal femur, with pathological diagnosis of osteosarcoma secondary to fibrous dysplasia. At 6 months post-operatively, transverse STIR MRI (C) demonstrated a solid, irregular-shaped mass of 6 mm in diameter on the distal femur lateral to prosthesis. The mass was very similar to an early detected small-sized LR of osteosarcoma, despite a lesser extent of peritumour infiltration. However, it slightly regressed and remained asymptomatic during the next 2 years, thus being considered pseudotumour (D). T2WI = T2-weighted imaging; STIR = short time inversion recovery; MRI = magnetic resonance imaging; LR = local recurrence.
Clinical results [24,28]. But solid lesions could bring out relevant clinical symptoms. Cystic lesions might relate to sterile inflammation, while solid lesions mainly to necrotic tissue [25]. In our study, nonprogressive pseudotumours also occupied a large proportion of pseudotumours, which were composed of cystic and solid masses. Similarly, none of them was associated with recurrence and revision surgery. Periprosthetic fluid and muscle oedema were also commonly normal changes in prosthesis surgery. Periprosthetic fluid was found in almost all of our patients, and we do not consider it as a meaningful indicator for recurrence. Sabah et al. found muscle oedema in eight patients with metal-on-metal hips, but they did not analyse the reason for these conditions [25]. We felt that such conditions might be related to muscular reaction to prosthesis and surgery trauma.

Periprosthetic fluid and muscle oedema were also commonly normal changes in prosthesis surgery. Periprosthetic fluid was found in almost all of our patients, and we do not consider it as a meaningful indicator for recurrence. Sabah et al. found muscle oedema in eight patients with metal-on-metal hips, but they did not analyse the reason for these conditions [25]. We felt that such conditions might be related to muscular reaction to prosthesis and surgery trauma.

Figure 5  Cystic local recurrent tumour mimicking pseudotumour. (A) A progressively enlarged mass was found in the left proximal tibia with a history of conventional osteosarcoma. A coronal STIR MRI image demonstrated a cystic mass (arrowhead) of 1.7 cm lateral to proximal prosthesis. Note its slightly more ill-defined edge towards adjacent muscle with weak muscular oedema. The mass was subsequently resected, with pathology being a recurrent malignancy. Interestingly, (B) showed that another local recurrent mass reappeared at another proximal site with very similar appearance to the recurrence in (A) 2 months after the second surgery. A cystic asymptomatic pseudotumour in another osteosarcoma patient was shown in (C) and (D). This pseudotumour was highly similar to (A) and (B), except that it was communicated with a joint cavity. After 6 months, cystic pseudotumour was shown to be regressed with an irregular contour (arrowhead) (E).

STIR = short time inversion recovery; MRI = magnetic resonance imaging.

Table 4  Radiological features on MR imaging for nodular/mass-like signal ≤2.1 cm.

| Radiological feature | Classification | Pseudotumours | LR | P value     | b value | Odds ratio | Confidence interval |
|---------------------|----------------|---------------|----|-------------|---------|------------|---------------------|
| Peritumour oedema   | Absent         | 5             | 6  | 0.01*       | −0.48   | 0.62       | 0.41 − 0.94         |
|                     | Present        | 3             | 5  |             |         |            |                     |
| Cystic vs solid     | Mixed solid    | 3             | 8  | 0.03*       | −0.44   | 0.64       | 0.44 − 0.95         |
|                     | Cystic         | 7             | 1  |             |         |            |                     |
| Infiltration        | Absent         | 10            | 6  | 0.01*       | 0.74    | 2.09       | 1.13 − 3.84         |
|                     | Present        | 0             | 3  |             |         |            |                     |

MR = magnetic resonance; LR = local recurrence.
Continuous variables are described as median (range).
*Significant in multivariate logistic model with backward selection method.
Figure 6  ROC for the predictive model. AUC of this ROC was 0.93, indicating high diagnostic accuracy for the predictive model of three significant variables. ROC, receiver operating characteristic curve; AUC, area under curve.

We acknowledged some limitations in our study. First, enhanced MRI has not been performed in the majority of our patients. Although it has been reported that static enhanced MRI obtained 2–5 min after contrast medium injection was not always able to differentiate between tumour recurrence and benign changes, dynamic contrast-enhanced (DCE) MRI was considered to be very helpful owing to the unique pattern of fast enhancement of recurrence [29,30]. However, it was uncertain whether DCE MRI was available in patients after prosthesis replacement because of the influence of metal artifacts. According to our results, large masses and certain typical malignant manifestation of small masses less than 2.1 cm could avoid some unnecessary enhanced examinations. So DCE MRI should be optimized in terms of image quality and applied in some unequivocal masses to detect LRs in postsurgical follow-up in the future. Second, the sample size was relatively small, and patients included were mainly performed by MRI because of suspicious clinical and radiological manifestations, which would lead to some extent of selection bias. That was why the recurrent rate in our study was relatively high. Future studies should include all patients who performed routine MRI postoperatively. Finally, lacking long-term follow-up did not allow us to know about MRI signs of long-term recurrence and complications.

Conclusion

In conclusion, for patients with prosthesis, we could detect the recurrence and diverse benign complications or conditions based on post-operative MRI. A mass larger than 2.1 cm was highly specificity for recurrence. When a mass was smaller than 2.1 cm, more solid property, more adjacent tissue infiltration, and less muscular oedema indicated recurrence rather than a benign mass.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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