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SCIENTIFIC ARTICLE

Small soft tissue masses indeterminate at imaging: histological diagnoses at a tertiary orthopedic oncology clinic

Kevin Pham [1] · Nisreen S. Ezuddin [1] · Juan Pretell-Mazzini [2,3] · Ty K. Subhawong [1,3]

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Abstract

Objective To review histologic diagnoses of soft-tissue masses (STMs) ≤ 2 cm with indeterminate imaging features encountered in musculoskeletal oncology clinic at a tertiary referral center.

Materials and methods This was an IRB-approved retrospective review of patients with STMs ≤ 2 cm, referred to our tertiary care orthopedic oncology clinic over 4.75 consecutive years. Maximum diameter was based on imaging measurement by a fellowship-trained musculoskeletal radiologist. Simple lipomas, synovial cysts, metastases, and cases without histologic confirmation were excluded. Patient demographics, tumor imaging features (location, depth, size, and tumor:muscle enhancement and T2 signal ratios), and histology were recorded and compared.

Results Mean maximum diameter for 42 trunk/extremity STMs was 1.5 cm (range, 0.7 to 2 cm). Mean age was 48 years (range, 18–83 years). Nine (21%) of the masses were malignant, while 33 (79%) were non-malignant. Thirty-nine (93%) of masses were superficial; 7/39 (18%) of these superficial tumors were malignant. Malignancy was not associated with underlying vessels, tendon, or fascia ($p = 0.19$). The non-malignant vs. malignant tumor:muscle enhancement ratio was 2.15 vs. 2.32 ($p = 0.58$) and enhancement coefficient of variation was 0.14 vs. 0.10 ($p = 0.29$). Most common malignant histologic subtypes were synovial sarcoma ($n = 3$), fibroblastic/myofibroblastic sarcoma ($n = 2$), leiomyosarcoma ($n = 2$), myxofibrosarcoma ($n = 1$), and angiomatoid fibrous histiocytoma ($n = 1$). The majority (67%) of non-malignant lesions were: leiomyoma ($n = 6$), angiomyoma ($n = 5$), schwannoma ($n = 4$), benign fibrous histiocytoma ($n = 4$), and hemangioma ($n = 3$).

Conclusions At a tertiary musculoskeletal oncology referral clinic, primary STMs ≤ 2 cm with indeterminate imaging features should be managed cautiously despite their small size and/or superficial location.

Keywords Soft tissue mass · Sarcoma · MRI · Ultrasound · Indeterminate

✉ Ty K. Subhawong
tsubhawong@med.miami.edu; tsubhawong@miami.edu

Kevin Pham
kxp384@med.miami.edu

Nisreen S. Ezuddin
nse78652@med.miami.edu

Juan Pretell-Mazzini
j.pretell@med.miami.edu

[1] Department of Radiology, University of Miami Miller School of Medicine/Jackson Memorial Hospital, 1611 NW 12th Ave, JMH WW 279, Miami, FL 33136, USA

[2] Department of Orthopaedic Surgery, University of Miami Miller School of Medicine, Miami, FL 33136, USA

[3] Sylvester Comprehensive Cancer Center, University of Miami Miller School of Medicine, Miami, FL 33136, USA

Introduction

Differentiating benign and malignant soft tissue masses (STMs) is challenging for radiologists since both categories have overlapping imaging and presenting features. While malignant masses are generally larger in size than benign masses [1], some slower-growing soft tissue sarcomas (STS) may come to attention at a surprisingly diminutive size. The American Joint Committee on Cancer (AJCC) 8th edition has added emphasis on tumor size, with T stage determined by maximum tumor diameter (T0: no evidence of primary; T1 ≤ 5 cm; T2 > 5 cm and ≤ 10 cm; T3 > 10 cm and ≤ 15 cm; T4 > 15 cm), and eliminated the staging influence of tumor depth [2]. Despite guidelines emphasizing the correlation with size and malignancy, Datir et al., in a prospective study of 571 patients, found that as much as 10% of the malignant lesions were < 5 cm and the most common malignant

diagnoses of these were synovial sarcoma, spindle cell sarcoma, and leiomyosarcoma [3]. Small malignant tumors may lack more aggressive features often (but not exclusively) seen in higher-grade malignant sarcomas such as peritumoral edema/enhancement or internal hemorrhage [1, 4]. Thus, misleading imaging, clinical presentation, or surgeon inexperience may result in STS unplanned excision and failure to achieve tumor-free margins [5].

While the majority of small superficial masses do not undergo imaging evaluation, those that are seen by radiologists, including those seen incidentally, pose a challenge with respect to subsequent steps in management. There have been prior studies where smaller tumor size was associated with benignity, such as Berquist et al. who reported 100% of their 11 masses < 3 cm were benign [1, 6–9], but size alone is unreliable as a sole criterion in assessing the nature of the tumor. To our knowledge, the literature of a differential diagnosis for STMs specifically ≤ 2 cm is scarce. By excluding simple lipomas, juxta-articular cysts, metastases, and soft-tissue lesions without histological confirmation, the purpose of our study is to investigate the most common histologic diagnoses likely to be encountered in a tertiary orthopedic oncology clinic among STMs ≤ 2 cm diameter.

Materials and methods

Subjects

Institutional Review Board (IRB) approval was obtained for this study. In accordance with the requirements of a retrospective review, requirement for informed consent was waived. All patients were referred to our institution's orthopedic oncology clinic at a tertiary care center over a period of almost 4.75 consecutive years (November 2013 through July 2018). Patients were identified from a list of cases discussed at our clinical sarcoma board. We retrospectively reviewed the clinical data and re-reviewed the imaging studies for patients discussed at this conference who met our inclusion/exclusion criteria. Retrospective review of electronic medical records was used for examination of clinical records and radiologic imaging. Data collected included patient demographics, tumor size, tumor depth, method of biopsy, and histological diagnosis. Exclusion criteria included masses > 2 cm in maximum diameter and those without histological confirmation; simple lipomas, synovial cysts (including paralabral or parameniscal cysts), subungual glomus tumors, superficial plantar and palmar fibromas, intra-articular masses, soft tissue or nodal metastases, and recurrent neoplasms were also excluded. The three metastatic lesions excluded were one melanoma of the foot, one follicular lymphoma of the shoulder, and a melanoma of the lower back. Metastatic and recurrent tumors were excluded since these lesions arise in a clinical context distinct from undiagnosed STMs. Final diagnosis was based on pathology reports from a dedicated bone and soft tissue pathologist. The final study group consisted of 42 patients with primary trunk or extremity STMs evaluated on MRI or ultrasound.

Imaging assessment

The exclusion criteria of > 2 cm was selected to allow us to focus on radiologically challenging cases where malignant potential may be discounted due to small size; while 2 cm is an arbitrary threshold for trunk and extremity tumors, it is used to define T1 stage in head and neck sarcomas and gastrointestinal stromal tumors [2]. Screening for size of the lesions was determined by imaging measurement performed by a fellowship-trained musculoskeletal radiologist.

A standardized imaging protocol was not used for our study since a number of exams originated from outside facilities. All imaging was reviewed by a fellowship-trained musculoskeletal radiologist (TS, 6 years' experience). All patients underwent imaging before biopsy or surgical excision. Six masses were assessed using ultrasound, and 36 by MRI. When multiple imaging studies were available, the earliest MRI that depicted the lesion was chosen for evaluation. Lesion size was measured in longitudinal, anterior-posterior, and transverse dimensions. The maximal diameter was identified and recorded. Lesion enhancement was assessed as being present or absent if the patient received intravenous contrast. Depth was determined relative to the investing muscle fascia on cross-sectional imaging. Any penetration into or beyond the muscle fascia was characterized as a deep lesion, and those entirely contained with the subcutaneous tissues superficial to the fascia were characterized as superficial.

Tumor:muscle enhancement mean signal ratios were calculated for those patients who received intravenous gadolinium. To do this, regions of interest (ROIs) were manually drawn around the mass on the slice depicting the greatest tumor diameter, and circular ROIs (measuring ≥1 cm diameter) were placed in nearby normal muscle, using the contrast-enhanced fat-suppressed T1-weighted images. Tumor:muscle T2 signal intensity ratios were similarly calculated using a corresponding fluid-sensitive sequence. The heterogeneity of tumor enhancement and T2 signal was also measured by calculating the coefficient of variation (std. deviation/mean) within the tumor ROIs. The presence of any tail-like signal adjacent to the tumor, as well as the relationship of the tumor to adjacent structures such as tendons, muscle fascia, nerves or vessels, was also recorded. We defined a tail-sign as a T2 hyperintense tapering, pointed, or curvilinear signal projecting away from an unencapsulated main tumor margin.

Statistical analysis

Wilcoxon rank-sum was used to analyze the differences in age and tumor imaging characteristics between non-malignant and

malignant groups. Fisher exact test was used to compare differences in gender between groups. All statistical analysis was performed using Stata Statistical Software: Release 13 (StataCorp LP). For all analyses, a p value of ≤0.05 was considered significant.

Results

Demographics

Of the 42 patients included in our study 23 (55%) of the patients were male, 19 (45%) were female. The overall mean patient age was 48 years. For the malignant subgroup ($n = 9$), the mean age was 41.6 (range, 17.9 to 69.2) while for the non-malignant (benign and non-neoplastic, $n = 33$) the mean age was 50.4 (range, 19.3 to 82.6); this difference was not statistically significant ($p = 0.17$, Wilcoxon rank-sum). Women comprised 16/33 (48%) of patients with non-malignant lesions, and 3/9 (33%) with sarcomas. Gender differences between non-malignant and malignant groups were not statistically significant ($p = 0.48$).

Imaging size, depth, enhancement, and location

On imaging, the mean maximum tumor diameter across all lesions was 1.5 cm. Table 1 compares the imaging size, depth, and enhancement between the nine malignant masses and the 33 non-malignant masses. The overall mean diameter for the malignant masses was slightly larger at 1.8 cm (range, 1.3 to 2) vs. non-malignant 1.4 cm (range, 0.7 to 2), $p = 0.01$, Wilcoxon rank-sum. No malignant tumors were < 1 cm in maximum diameter. Thirty-nine (93%) masses were superficial, while three (7%) were deep. Only one (3%) of the non-malignant lesions were deep (a schwannoma). Two of the three (66%) deep tumors were malignant, vs. seven of 39 (18%) superficial tumors were malignant ($p = 0.11$, Fisher's exact). Two cases were in the chest/trunk; all other masses were in the extremities, with ten in the upper extremity and 30 in the lower extremity.

MRI assessment was performed for all except six subjects, all of whom had non-malignant tumors. Masses in all patients who received contrast ($n = 23$) showed variable degrees of enhancement, whether non-malignant or malignant. There were no statistically significant differences between malignant and non-malignant lesions in terms of tumor:muscle enhancement ratio or tumor enhancement heterogeneity. Mean (± std. dev) tumor:muscle enhancement ratio for non-malignant tumors ($n = 17$) was 2.15 (± 1.04) vs. malignant ($n = 6$) 2.32 (± 0.77) ($p = 0.58$, Wilcoxon rank-sum), and tumor enhancement coefficient of variation was 0.14 (± 0.08) vs. 0.10 (± 0.05) ($p = 0.29$, Wilcoxon rank-sum). T2 signal intensity was evaluable for 36 subjects, and also failed to show statistically different results between benign ($n = 27$) and malignant ($n = 9$) lesions. Mean (± std. dev) tumor:muscle T2 signal ratio was 2.97 (± 1.93) vs. 2.37 (± 1.13) for non-malignant vs. malignant ($p = 0.48$, Wilcoxon rank-sum), and T2 signal intensity coefficient of variation was 0.18 (± 0.11) vs. 0.21 (± 0.18) ($p = 0.81$, Wilcoxon rank-sum). Table 1 summarizes tumor relationships to underlying anatomy. There was no correlation between malignancy and the presence of a tail-like

Table 1 Tumor maximum diameter, depth, and enhancement of non-malignant vs. malignant masses

Imaging features	Non-malignant ($n = 33$)	Malignant ($n = 9$)	p
Diameter mean (range)	1.4 cm (0.7–2 cm)	1.8 cm (1.3–2 cm)	0.01[a]
Deep	1	2	0.11[b]
Superficial	32	7	
Tumor:muscle enhancement ratio (SD)	2.15 (±1.04, $n = 17$)	2.32 (±0.77, $n = 6$)	0.58[c]
Enhancement coefficient of variation	0.14	0.10	0.29[c]
Association			0.19[d]
None	13	1	
Nerve	2	0	
Vessel	1	1	
Tendon	6	4	
Fascia	5	3	

[a] Statistically significant at alpha = 0.05, determined using Wilcoxon rank-sum

[b] Fisher's exact test was used for testing differences between non-malignant and malignant tumors with respect to tissue depth

[c] Wilcoxon rank-sum was used for testing differences of tumor:muscle enhancement ratio and enhancement coefficient of variation between non-malignant and malignant tumors

[d] Tumor associations with underlying anatomic structures as identified by MRI. The tumor was considered to be associated with the structure if it was in-continuity or in contact with the structure for > 25% of the mass's peripheral margin. Fisher's exact test was used for testing differences of association with underlying anatomic structures between non-malignant and malignant tumors

signal adjacent to the tumor, as 8/27 (30%) benign lesions and 4/9 (44%) malignant lesions displayed this finding ($p = 0.34$, Fisher's exact test). Two schwannomas, but no malignant tumors, were associated with a nerve; otherwise there was no clear association between malignant masses and an underlying structure ($p = 0.19$, Fisher's exact test).

Histology

Histology was obtained by punch biopsy in two (5%), percutaneously in 16 (38%), and by excisional biopsy in 24 (57%) cases. Table 2 illustrates the histologic subtypes for benign, malignant, and non-neoplastic lesions. Nine of 42 (21%) of masses were malignant, while 33 (79%) were non-malignant. The malignant masses included synovial sarcoma ($n = 3$), fibroblastic/myofibroblastic sarcoma ($n = 2$, one grade 2 and one grade 3), leiomyosarcoma ($n = 2$, one grade 2 and one grade 3), and myxofibrosarcoma ($n = 1$, grade 3); angiomatoid fibrous histiocytoma ($n = 1$) was included given its intermediate aggressivity and malignant potential [10]. The most common benign neoplasms were leiomyoma ($n = 6$), angiomyoma ($n = 5$), benign fibrous histiocytoma ($n = 4$), schwannoma ($n = 4$), and hemangioma ($n = 3$); additional benign entities included a variety of non-neoplastic lesions such as epidermal inclusion cyst ($n = 2$).

Clinical outcome of sarcomas

For the nine malignancies, mean time from earliest tumor-depicting MRI to definitive excision was 19.5 months (range, 1.6–67 months); this includes two synovial sarcomas with a documented 5-year interval between earliest available MRI and definitive excision. All but one patient were free of disease at the last clinical follow-up: mean disease-free survival was 27 months (excluding an angiomatoid fibrous histiocytoma, lost to follow-up after surgery). One patient with a 1.7-cm leiomyosarcoma was lost to follow-up for 9 months until representing with the mass enlarged to 5 cm, and he developed lung metastases 7 months after definitive excision. Three tumors underwent unplanned excision (all with positive or indeterminate margins), and were subsequently treated with radiation and definitive tumor bed excision. Five tumors were diagnosed by percutaneous biopsy, and one underwent an excisional biopsy converted to a wide local excision after intra-operative frozen pathology demonstrated sarcoma. Five of nine subjects were radiated prior to definitive tumor or tumor bed excision; three received adjuvant radiation post-operatively.

Discussion

Several studies in literature have shown that STMs of both benign and malignant nature share overlapping imaging features [4, 11, 12]. Clinically, radiologists are often challenged when they encounter an STM and must consider the fact that many imaging findings are nonspecific. In this study, we retrospectively evaluated STMs ≤ 2 cm of 42 patients, and confirmed our anecdotal experience that distinguishing benign from malignant nonlipomatous solid lesions in this size range is often not possible based on imaging alone.

There was a statistically significant difference in mean size between the non-malignant and malignant lesion groups in this series, but this 4-mm difference would be negligible in the assessment of individual tumors. While absence of contrast enhancement may be useful in excluding neoplasms, solid enhancement can be seen in a number of benign neoplasms as well. In this series of STMs ≤ 2 cm, both non-malignant and malignant tumors showed variable tumor enhancement (signal normalized to muscle) and heterogeneity (as quantified by coefficient of variation). However, while attempts were made to normalize contrast enhancement avidity T2 signal (by using tumor:muscle signal ratios and coefficients of variation) so that comparisons between subjects could be performed, the high variability in examination protocols limits any quantity-specific conclusions that can be drawn from these ratios themselves. For example, the highest tumor:muscle enhancement

Table 2 Musculoskeletal radiology encountered soft tissue masses ≤ 2 cm

Benign ($n = 25$)		Malignant ($n = 9$)		Non-neoplastic ($n = 8$)	
Angiolipoma	1	Angiomatoid fibrous histiocytoma	1	Ectatic vein with papillary endothelial hyperplasia	1
Angiomyoma	5	Leiomyosarcoma	2	Epidermal inclusion cyst	2
Benign fibrous histiocytoma	4	Fibroblastic/myofibroblastic sarcoma	2		
Hemangioma	3[a]	Myxofibrosarcoma	1	Granuloma annulare	1
Leiomyoma	6[b]	Synovial sarcoma	3	Hypertrophic dermal cicatrix	1
Myopericytoma	1			Thrombus	1
Schwannoma	4			Neuroma	1
Superficial acral fibromyxoma	1			Organizing hematoma	1

[a] Includes 1 arteriovenous, 1 venous, and 1 cavernous hemangioma

[b] Includes 2 angioleiomyomas and 1 pilar leiomyoma

ratio was observed in a benign lesion, suggesting these ratios may be driven more by the technical scanning parameters that vary across sites than by tissue-level conventional enhancement characteristics. Prior studies have shown that malignant lesions may be differentiated by dynamic enhancement characteristics [13, 14], and future studies might explore DCE parameters among tumors in this size range to determine if enhancement kinetics are more predictive of tumor malignancy than normalized enhancement ratios or enhancement heterogeneity.

Our results further corroborate prior studies, which have emphasized that size is a poor criterion to differentiate between benign and malignant tumors [15, 16]. With regard to depth in relation to the fascia, our study showed a large proportion (7 of 9) of malignant lesions in our study group were superficial to the fascia. While earlier staging systems assigned higher stage to deep tumors, the most recent AJCC guidelines removed tumor depth as a criterion in staging/risk stratification of soft tissue sarcomas behavior [2]. Although malignant lesions tend to be deep and benign lesions tend to be superficial, a non-negligible number of soft-tissue sarcomas may be superficial [3, 17]. Thus, this criterion alone is of limited value in predicting the nature of the tumor (Figs. 1, 2, 3, 4 and 5).

Superficial STSs may come to clinical attention due to their location, which allows for easier detection than a deep sarcoma [3, 18]. Among the nine of 42 (21%) of our ≤ 2 cm STMs that were malignant, three were synovial sarcomas, and one experienced a delay in diagnosis of approximately 5 years from initial presentation (Fig. 6). While confirmation of lesional stability over time is reassuring of benignity, it should be noted that synovial sarcomas, in particular, may exhibit an indolent growth rate and thus take an average of 2–4 years to diagnose after initial symptoms, and are commonly small in size upon presentation [19]. Datir et al. also found that their most common malignant lesions < 5 cm were synovial sarcomas (nine of 30 cases) [3]. Our other malignant tumors included one myxofibrosarcoma, two fibroblastic/myofibroblastic sarcomas, and two leiomyosarcomas; all of these tumors were grade 2 or grade 3 histologically. This aligns with a large retrospective study performed at the Armed Forces Institute of Pathology (AFIP) showing a fibrosarcoma prevalence of 8% and a leiomyosarcoma prevalence of 8% [20]. These subtypes have also been commonly found in previous studies investigating small STMs as well [3, 21, 22]. Dyrop et al. reports that STSs, because of size and other non-specific features, are often improperly worked up, leading to suboptimal treatment [23]. Three of our malignant lesions underwent

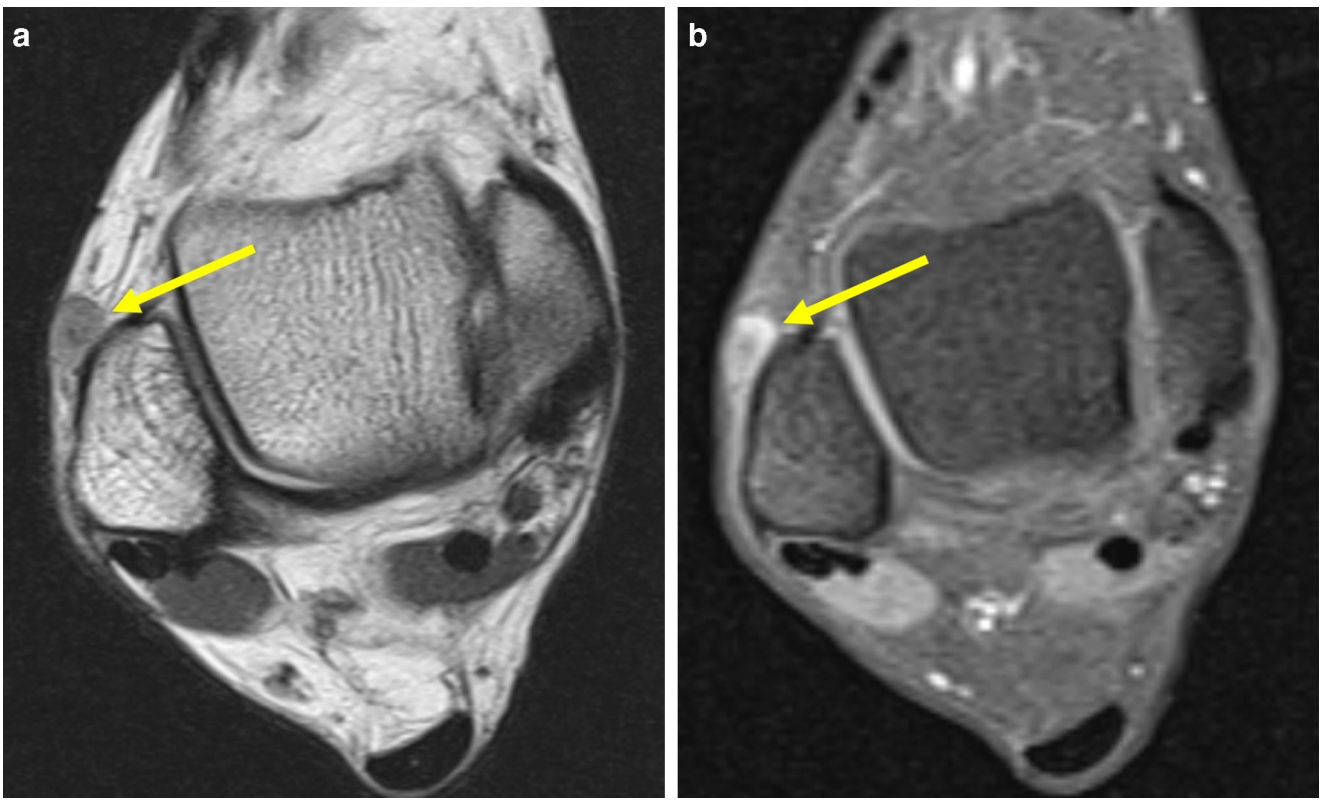

Fig. 1 A 58-year-old woman with a painful ankle mass. **a** Axial proton density-weighted MRI depicts a 0.8-cm subcutaneous nodule over the lateral malleolus (*arrow*); there is no discernable internal fat signal. **b** Axial post-contrast fat-suppressed T1-weighted MR image shows heterogeneous enhancement. This nodule was surgically excised, with final pathology revealing angioleiomyoma

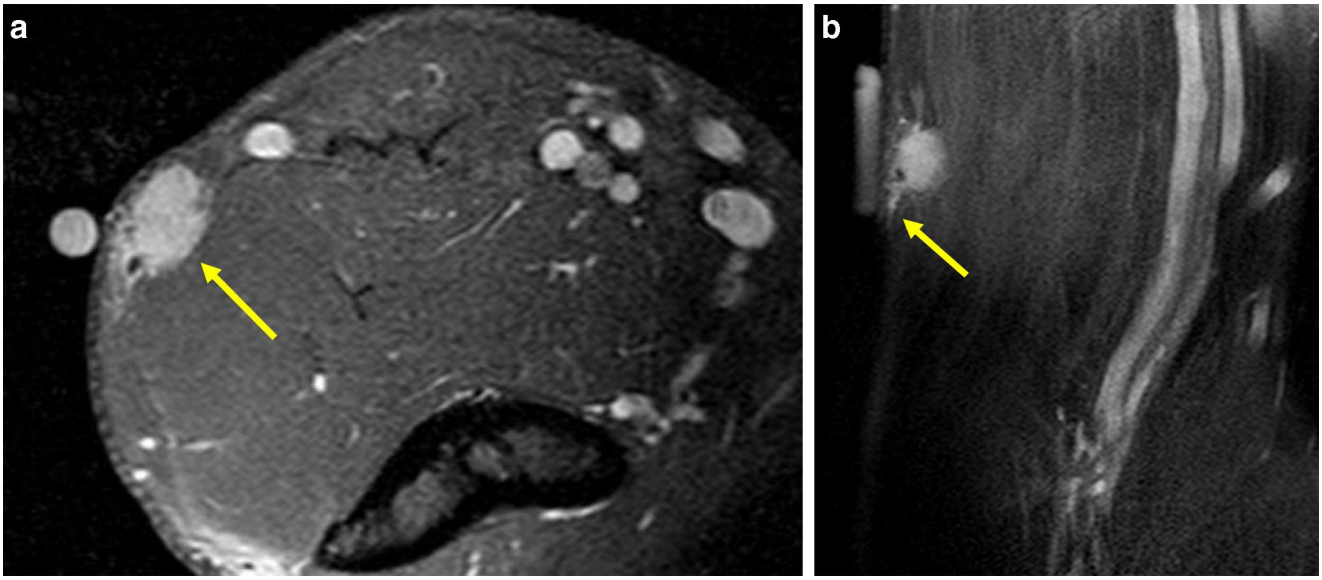

Fig. 2 A 55-year-old man with a palpable elbow mass. **a** Axial post-contrast fat-suppressed T1-weighted MR image shows an enhancing 2-cm subcutaneous mass (*arrow*), involving the investing muscle fascia. **b** Coronal proton density-weighted MRI shows a subtle tumor tail (*arrow*) infiltrating into the adjacent subcutaneous tissues and along fascial planes, a feature characteristic of, but not specific to, myxofibrosarcoma, which was confirmed on excisional biopsy to be high grade

unplanned excision, and all of these subsequently underwent tumor bed excision with adjuvant radiation. Unplanned excisions increase the risk of local recurrence, and may require larger soft-tissue reconstructions due to the need for tumor bed excision, as emphasized by Pretell-Mazzini, et al. [5]. Failure to entertain sarcoma early in the differential diagnosis can delay treatment and lead to local complications and inferior outcomes [24].

Non-malignant lesions are more commonly encountered at smaller sizes with only 5% of benign soft tissue tumors exceeding 5 cm in diameter [22, 25]. We found that a majority (79%) of our ≤ 2 cm lesions were non-malignant as well. Most (67%) of our benign lesions were one of five subtypes: leiomyoma ($n = 6$), angiomyoma ($n = 5$), benign fibrous histiocytoma ($n = 4$), schwannoma ($n = 4$), and hemangioma ($n = 3$). Similarly, AFIP found that 70% of their benign lesions

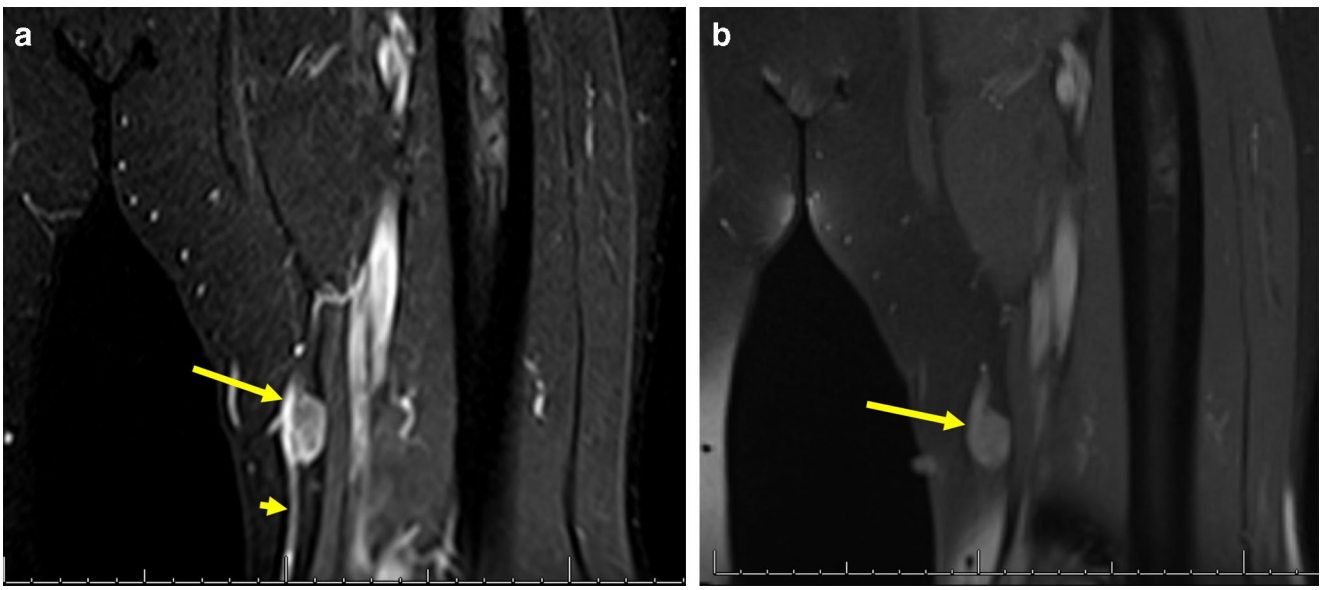

Fig. 3 A 64-year-old man with a painful thigh mass. **a** Fat-suppressed coronal proton density-weighted MRI shows a 1.9-cm hyperintense subcutaneous nodule (*arrow*) arising from the greater saphenous vein (*arrowhead*). The relationship with the vein is suggestive of leiomyoma or leiomyosarcoma. **b** Coronal contrast-enhanced fat-suppressed T1-weighted MR image confirms solid enhancement pattern. This was confirmed as a leiomyosarcoma on excisional biopsy

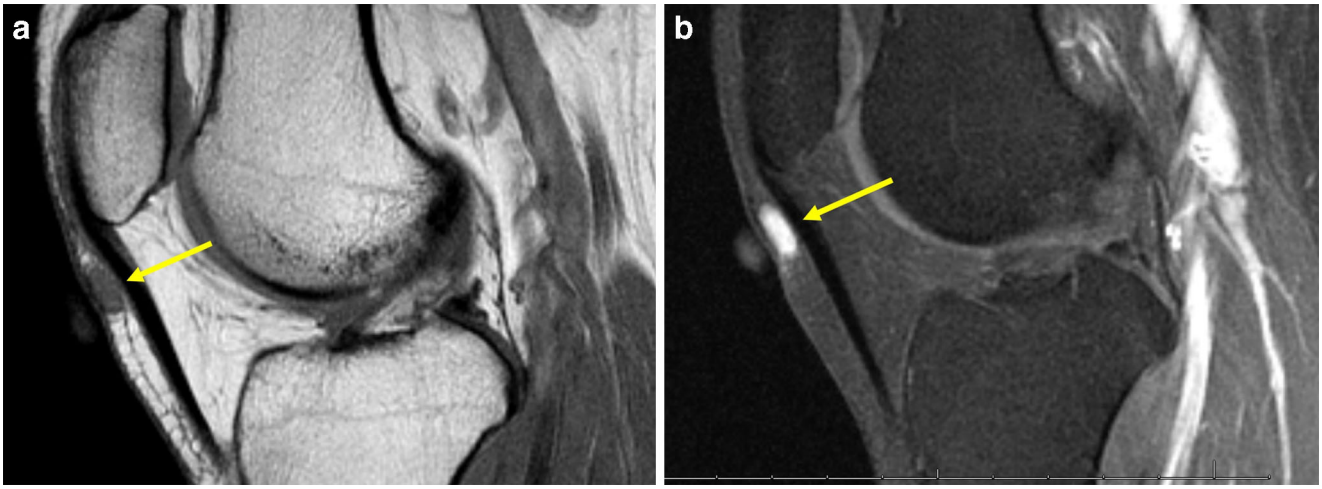

Fig. 4 A 32-year-old woman with a palpable non-tender knee mass. **a** Sagittal proton density-weighted MR image shows a 1.2-cm isointense subcutaneous nodule (*arrow*) in the prepatellar soft tissues. **b** Sagittal contrast-enhanced fat-suppressed T1-weighted MR image reveals homogenous enhancement in this angiomyoma (*arrow*), which underwent excisional biopsy

fell into one of eight diagnostic categories, which included lipoma and lipoma variants (16%), fibrous histiocytoma (13%), nodular fasciitis (11%), hemangioma (8%), fibromatosis (7%), neurofibroma (5%), and schwannoma (5%) [26]. Two of the tumors in our study were angioleiomyomas, which we included under the broader category of leiomyomas in our study; angioleiomyomas are known to manifest as small subcutaneous masses in the extremities, with Yoo et al. showing in their series that 5/8 (63%) were ≤ 2 cm in maximum diameter [27]. We excluded simple lipomas because in this size range, we suspect many, if not most, will be radiologically occult even if clinically palpable; furthermore, MRI is considered definitive for simple lipoma or low-grade lipomatous neoplasm. Juxta-articular synovial, paralabral and parameniscal cysts, as well as superficial plantar/palmar fibromas, were excluded for a similar reason: they are a common occurrence and can be definitively diagnosed on MRI.

This study has several limitations, perhaps foremost of which is its small sample size. Because our institution is a tertiary referral center with an active orthopedic oncology practice, there is a selection bias toward malignant lesions. Because we focused on small *indeterminate* STMs, which required biopsy or excision for definitive diagnosis, many of the most common STMs, such as simple lipomas or small foci of intra-articular tenosynovial giant cell tumor, were excluded because of their determinate or highly suggestive imaging features, thereby inflating our observed frequency of malignant superficial lesions. The lesions represented here reflect those seen primarily on MRI and reviewed by a single musculoskeletal radiologist at a tertiary care center. We emphasize that this study result does not represent the spectrum of lesions

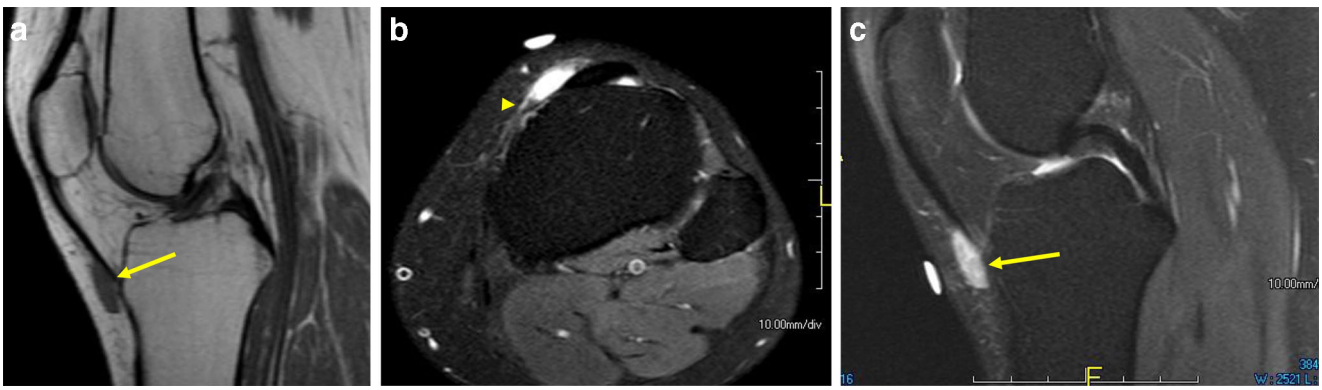

Fig. 5 A 24-year-old woman with a non-tender palpable subcutaneous knee mass. **a** Sagittal T1-weighted MRI shows a 1.5-cm hypointense nodule superficial to the patellar tendon (*arrow*). **b** Axial proton density-weighted MRI obtained 4 years later shows essentially no growth, with mild peritumoral soft tissue edema (*arrowhead*) extending medially from the tumor. **c** Sagittal contrast-enhanced fat-suppressed T1-weighted MRI reveals solid homogenous enhancement in this monophasic synovial sarcoma, which underwent excisional biopsy, with positive margins

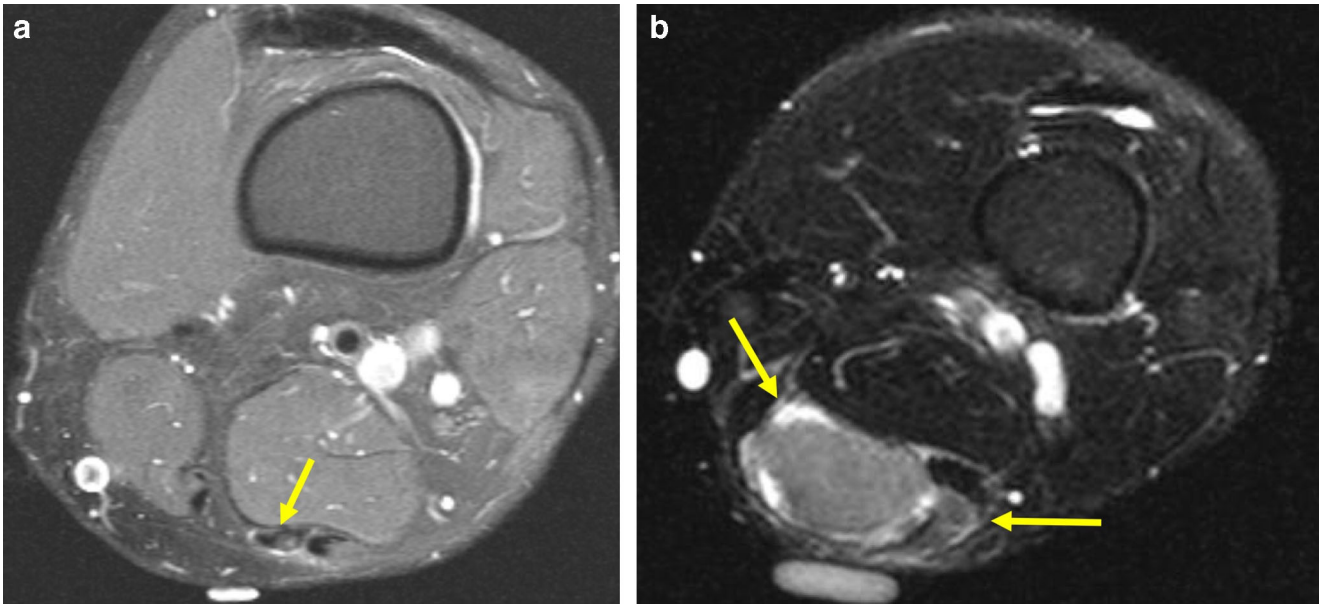

Fig. 6 A 41-year-old man with a non-tender palpable posterior thigh mass. **a** Axial proton density-weighted MRI shows a predominantly hypointense 1-cm mass (*arrow*) adjacent to the semimembranosus muscle fascia, and just medial to the semitendinosus tendon. The patient was lost to follow-up. **b** Axial fat-suppressed T2-weighted MRI 5 years later shows significant enlargement of the mass (*arrows*), now measuring 4 cm in diameter; note the heterogeneity of internal signal, with components of varying hyper-, iso-, and hypo- intensity within the mass. Biopsy later confirmed a high-grade biphasic synovial sarcoma

seen in a general clinical setting, as many superficial lesions, particularly epidermal inclusion cysts, pilomatricomas, and other skin appendage lesions that might be regularly seen in a dermatology practice, are under-represented [28]. This is probably because such lesions are diagnosed clinically and rarely come to imaging attention, or are diagnosed as benign based on a combination of clinical and radiological features, especially imaging stability over time. As a result, these STMs may be infrequently biopsied or excised. Another limitation we briefly mentioned before, is the lack of a standardized imaging protocol with exams done at other facilities. Interpreting data points from MRI exams with a potential for a wide range of parameters, such as tumor enhancement, should be approached with caution; however, variation was minimized in our study by having one musculoskeletal radiologist perform all the enhancement analysis. Furthermore, we suspect that there is high regional variability, both within and between countries, in whether small masses ≤ 2 cm are referred for imaging, without good consensus guidelines [29]. Regional and practice-dependent referral patterns will influence how often these masses are encountered by radiologists, and we stress that our results reflect our experience at a US tertiary referral center.

Conclusions

Our study shows that primary soft tissue sarcomas are not rare among masses of small size after excluding common cysts and lipomas. Solid lesions ≤ 2 cm still need careful clinical and imaging follow-up, and histologic correlation when appropriate.

Compliance with ethical standards

This study involving human subjects was performed in accordance with the ethical standards of the University of Miami Institutional Review Board and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of interest Kevin Pham: No potential conflicts of interest to disclose.

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