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Magnetic resonance and computed tomography imaging features of epithelioid sarcoma in children and young adults with pathological and clinical correlation: a report from Children's Oncology Group Study ARST0332

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Abstract

Objective—To correlate imaging features of epithelioid sarcoma in children and young adults enrolled in Children's Oncology Group study ARST0332 with clinical and pathological findings.

Materials and methods—Fifteen people (6 males; median age 16.1 years, range 6.5–24.8 years) with epithelioid sarcoma enrolled in ARST0332 had preoperative imaging (MRI, $n=10$; CT, $n=5$) that was reviewed by two radiologists who recorded numerous features including presence and percentage of tumor necrosis, presence of surrounding edema, and lymph node involvement. Discrepancies between reviewers were adjudicated by concurrent re-review. We correlated imaging findings with histological assessment of percentage tumor necrosis, proximal- vs. classic-type histology, lymph node involvement and recurrence.

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Results—Eleven patients (11/15, 73%) had proximal-type histology tumors. Ten of 14 tumors (71%) had imaging evidence of necrosis. Among the nine tumors with imaging and histological estimates of percentage necrosis, agreement was within 30% (in six tumors there was 10% difference between pathology and imaging). All 10 tumors imaged with MRI had surrounding edema. Four patients had biopsy-proven nodal involvement; all had necrotic nodes on imaging. There were four false-positives for nodal involvement by imaging. Twelve patients (12/15, 80%) had recurrences (local only, $n=1$; local and distant, $n=1$; distant only, $n=10$).

Conclusion—Proximal-type histology was prevalent in this young cohort with preoperative imaging. Necrosis is common in primary tumors and involved nodes. There is good agreement between histological and imaging estimates of primary tumor necrosis. Surrounding tumor edema is common in this tumor, which is known to spread along fascial planes.

Keywords

Adolescents; Children; Computed tomography; Epithelioid sarcoma; Magnetic resonance imaging; Young adults

Introduction

Epithelioid sarcoma is a rare tumor of variable biological behavior that accounts for <1% of all soft-tissue tumors [1]. It was first recognized in 1970 as a distinct tumor with multidirectional differentiation that is predominantly epithelial but of uncertain histogenesis [2]. Since then, the reported histomorphopathology, immunophenotype and ultrastructure of epithelioid sarcoma suggest that it is of mesenchymal origin [1]. Microscopically, it can mimic both benign and malignant tumors including nodular fasciitis, necrobiotic granuloma, benign and malignant fibrous histiocytoma, synovial sarcoma, and ulcerated squamous cell carcinoma [2-4]. It occurs at any age, has a peak incidence in young adults, shows a male predominance, and has associated antecedent trauma in 20% to 27% of cases [3-6]. Epithelioid sarcoma can arise in superficial or deep soft tissues and has a propensity to spread along fascial planes, aponeuroses and tendon sheaths. It is pathologically classified as being of the classic type (formerly referred to as distal type) or proximal type. The classic type tends to arise in extremity sites, especially the arm and hand, as subcutaneous or deep soft-tissue nodules with a pseudogranulomatous growth pattern, and they sometimes ulcerate (Fig. 1) [3, 4]. This variant contains cells with only mild atypia and epithelioid or spindled morphology, although recurrences might appear pleomorphic. The proximal variant often occurs in older adults and arises in axial regions including the limb girdles, pelvis, perineum, mediastinum and trunk. The proximal type displays large cells with a sometimes epithelioid appearance in sheets, and exhibits a more aggressive biological behavior (Fig. 1). It is important to note that the classic and proximal pathological types can each occur in either appendicular (upper arm, forearm, hand, thigh, calf, foot) or axial (head/neck, trunk, limb girdles) anatomical sites [3].

Epithelioid sarcoma has a high rate of recurrence, with subsequent local/regional lesions developing proximal to the primary tumor site. In a large series including 202 people, Chase and Enzinger [4] reported that 77% developed at least one local recurrence. In that study, 45% of subjects eventually developed metastatic disease that occurred as late as 39 years

after diagnosis [4]. Initial metastatic sites included lymph nodes (48%), lungs (25%), scalp (10%), skin other than scalp (6%), and less commonly the mediastinum, dura, liver, bone and brain [4]. Chase and Enzinger found that the amount of primary tumor necrosis paralleled metastasis; 34% of tumors with little or no necrosis metastasized compared to 88% of those that were largely necrotic. Additionally, tumors arising in the hand and finger were less likely to metastasize than others [4]. The median survival rate for patients without distant metastasis was approximately 88 months, versus 8 months for those with distant metastases [1,4]. Other poor prognostic features included proximal-type histology, proximal location, vascular invasion, inadequate excision, male gender, older age, deep location, tumor diameter >2.0 cm, higher mitotic rate, and lack of lymphocyte infiltrate in the primary tumor [4].

While the pathological and clinical features of epithelioid sarcoma have been well described, there is little literature describing its imaging features, especially in children [1, 7-15]. The Children's Oncology Group (COG) recently completed a 5-year multi-institutional trial (ARST0332) to investigate a risk-based strategy for treating patients younger than 30 years of age with non-rhabdomyosarcoma soft-tissue sarcomas. Of the 550 eligible patients, 29 (5.3%) received a histological diagnosis of epithelioid sarcoma; 15 of these patients had imaging performed before primary tumor resection. This provided an opportunity to methodically review the imaging features of epithelioid sarcoma in a relatively large cohort of young adults and children who underwent imaging with modern modalities and techniques. The purpose of our study was to correlate the imaging findings with clinical and pathological features in this distinct patient population.

Materials and methods

The study cohort included people with epithelioid sarcoma who were younger than 30 years and were enrolled in the COG protocol ARST0332 between February 2007 and February 2012. The study complied with the Health Insurance Portability and Accountability Act (HIPAA) and was approved by institutional review boards at the participating institutions. All participants or their guardians signed informed consent and assent as appropriate. Tumor pathology specimens of all patients were centrally reviewed by two study pediatric pathologists (C.M.C., with 28 years of clinical experience, D.M.P., with 27 years of clinical experience) to confirm the histological subtype of non-rhabdomyosarcoma soft-tissue sarcoma according to the 2002 World Health Organization (WHO) classification of soft-tissue tumors [16]. Of the 29 patients with epithelioid sarcoma, 15 had imaging before primary tumor resection that was available for review; 5 had CT only, 10 MRI only, and none had both CT and MRI. All patients were staged using CT or MRI of the primary tumor, chest CT, bone scan and local/regional lymph node sampling. Using the COG study database, we obtained demographics, primary tumor site and centrally reviewed pathological findings for all 29 patients with epithelioid sarcoma. For the 15 patients with preoperative imaging we also recorded sites of recurrence and correlated baseline imaging features with clinical findings.

Magnetic resonance and computed tomography scanning techniques and image review

Because imaging was obtained from numerous institutions, there was variability in scanning techniques. In general, MRI examinations included unenhanced T1-W, fat-saturated T2-W or short tau inversion recovery (STIR) coronal images; unenhanced T1-W and fat-saturated T2-W axial imaging; and contrast-enhanced fat-saturated axial and coronal T1-W sequences. Sagittal images were acquired in some patients for better tumor characterization. Axial CT imaging of the primary tumor was performed with intravenous contrast agent in 4/5 (80%) cases. Coronal and sagittal reconstructed CT images were available for 2/5 (40%) patients, and coronal-only for 1/5 (20%).

We sent all imaging to the Quality Assurance Review Center (QARC, Lincoln, RI), where it was anonymized and assigned unique identifiers. The imaging was centrally reviewed by the ARST0332 study radiologists (M.B.M. and S.C.K., both American Board of Radiology [ABR] certified with 12 and 30 years of clinical experience, respectively, at study initiation). The radiologist reviewers deemed all submitted imaging to be of diagnostic quality. The reviewers independently determined the primary tumor anatomical site; tumor volume (using the formula for an ellipsoid model — [anterior-posterior diameter x transverse diameter x longitudinal diameter] x 0.52); percentage tumor necrosis (estimated by subjectively determining the relative amount of non-enhancing, fluid density/intensity tumor compared to total amount of tumor); involvement of the main neurovascular bundle (defined as tumor not abutting, abutting or encasing); and bone involvement (defined as tumor not abutting, abutting but not invading, or invading). Volume measurements and percentage necrosis that varied by more than 20% between the two reviewers and discrepancies in neurovascular bundle and bone involvement were adjudicated by consensus re-review of the imaging. We also assessed the presence and location of metastatic disease at diagnosis based on central imaging review and, in some cases, confirmed by biopsy.

For purposes of the present study, re-review of imaging was performed concurrently by one study radiologist (M.B.M.) and a non-study ABR-certified radiologist with one year of clinical experience (C.G.) on an Intelrad picture archiving and communications (PACS) system (Westminster, CO); the workstation tools (e.g., window, level and magnification) were used at the reviewer's discretion. Using the MR sequences that best visualized tumor characteristics, the reviewers recorded tumor origin (muscle, fat or indeterminate); contour (smooth or lobulated); margins (sharp [$<50\%$ poorly defined] or infiltrative [$\geq 50\%$ poorly defined]); and presence of surrounding edema (hyperintense T2/STIR signal with enhancement on post-contrast T1-W images). Surrounding edema was further judged to be minimal (near tumor margins), moderate (within 2–3 cm of tumor margins), or marked (beyond 2–3 cm away from tumor margins). The reviewers also recorded the predominant tumor signal intensity ($\geq 50\%$ of total tumor) on T1-W, T2-W and STIR sequences as hypointense, hyperintense or isointense to muscle, or mixed (no signal intensity $\geq 50\%$), and noted the presence of hemorrhage (hyperintense on T1-W, hypointense on T2-W/STIR, non-enhancing). The enhancement pattern was categorized as homogeneous (the entire tumor), heterogeneous (part of the tumor, suggesting partial necrosis) or peripheral (suggesting predominantly necrotic), and degree of enhancement was recorded as mild (slightly visible), moderate (visible but less enhancing than vessels) or intense (greater than vessel

enhancement). When imaging of the local/regional nodal basin was obtained, the reviewers recorded the presence of abnormal lymph nodes (≥ 1.5 cm short axis or more numerous than expected) and whether the involved nodes were necrotic. They did not assess for presence of calcification by MRI because of the difficulty of confirming this finding by this modality. On CT, the reviewers assessed the tumor origin, calcifications, contour, margins, enhancement intensity, enhancement pattern and presence of abnormal lymph nodes (as described). They did not assess surrounding edema or hemorrhage by CT because of its limited diagnostic confidence for these parameters.

Pathology and surgical review

Two study pathologists (C.M.C., D.M.P.) centrally reviewed all tumor pathology specimens to confirm the histological diagnosis of epithelioid sarcoma. Diagnostic disagreements were reviewed and adjudicated by consensus. Study pathologists estimated percentage tumor necrosis of the primary tumor at baseline based on available histological sections. For purposes of the current study an ARST0332, study pathologist C.M.C. classified tumors as having proximal or classic histology according to 2013 World Health Organization (WHO) definitions [17]. Local/regional lymph node sampling was performed in all patients. The protocol surgical guidelines stated that when lymph nodes were clinically negative, sentinel lymph node biopsy was encouraged over random lymph node sampling. Tumor depth was defined by central surgical review according to the 6th edition of the American Joint Committee on Cancer (AJCC) Cancer Staging Manual [18] as superficial (tumor is superficial to and does not involve the superficial fascia) or deep (tumor is deep to or invades the superficial fascia). All intraperitoneal visceral tumors, retroperitoneal, pelvic and intrathoracic tumors and the majority of head and neck tumors were considered deep.

Results

Demographics, primary tumor sites, and histology of all 29 patients are shown in Table 1. Among the 15 patients with preoperative imaging, 12 were diagnosed by either upfront gross tumor resection ($n=9$) or primary tumor biopsy ($n=3$), and 3 by lymph node sampling. The MR and CT imaging features are summarized in Table 2. By imaging, the mean maximum tumor diameter was 5.9 cm, ranging from 1.2 cm for a hand primary lesion to 19.0 cm for an omental primary lesion (Table 3). The mean tumor volume was 160 mL (median, 12.7 mL; range, 0.3– 1,066.2 mL). Seven tumors involved the underlying osseous structures; six were abutting and one invading bone (Fig. 2). Five tumors (four deep, one superficial) encased the main neurovascular bundle, and three were abutting it (one superficial, two deep; Table 3). Percentage necrosis could not be assessed in three patients who were imaged by CT because of inadequate image quality. In the remaining 12, primary tumor necrosis ranged from 0% to 80%. Histological assessment of primary tumor necrosis at baseline was available for 9 of these 12. The imaging and histology estimates of percentage necrosis: (Table 3) varied by up to 30%, but the majority (6/9, 75%) were either concordant ($n=1$) or varied by only 10% ($n=5$). Based on the CT and MRI primary tumor enhancement pattern, 9 of 14 evaluable tumors (64%, Table 2) subjectively showed evidence of partial or predominant necrosis at diagnosis (Fig. 3).

Imaging review

On imaging, approximately half of the tumors had an indeterminate origin (7/15, 47%), the majority had margins that were lobulated (13/15, 87%) and infiltrative (10/14, 71%; proximal type, $n=7$, and classic type, $n=3$; Figs. 2, 3 and 4). Only two tumors had smooth margins: one superficial foot tumor and one deep chest tumor. Of the 10 tumors imaged by MRI, all had surrounding edema that was marked in 5 (50%; 3 proximal and 2 classic types). All 15 patients underwent lymph node biopsies; 10 had imaging examinations that included the local, regional, or distant nodal basins obtained prior to lymph node biopsy/resection. Five (5/15, 33%) had biopsy-proven nodal involvement. Four of these five had preoperative nodal basin imaging; all four had enlarged and necrotic nodes on imaging (Fig. 5). Lymph node involvement was suspected on imaging in four additional patients, all of whom had negative lymph node sampling. Two additional patients had non-biopsied satellite nodules vs. involved lymph nodes near the primary tumor site (Fig. 6). Two patients with nodal metastasis had lymph nodes that were larger than the primary tumor (foot and calf primary sites; Fig. 2).

Pathology review and outcome

Pathological features and corresponding clinical, surgical and imaging features are summarized in Table 3. Among all 29 patients with epithelioid sarcoma, 16 had classic histology and were slightly older (mean age, 14.4 years; range, 2.6–24.7 years) than the 13 with proximal histology (mean age, 13.1 years; range, 8.3–22.4 years). Among the 15 patients with preoperative imaging, 11 (73%) had proximal-type histology. Twelve of the 15 (80%) had recurrences between 42 days and 3.3 years from diagnosis (mean, 0.5 years): 1 had local recurrence only, 1 had local and distant recurrence, and 10 had distant metastatic recurrence only. Ten of these 15 patients died — 9 of disease progression and 1 of unknown cause. Among the 14 patients who did not have preoperative imaging, 12 (86%) had classic histology. Tumor size for 9 of these 14 tumors was available in the COG database and ranged from 0.2 cm to 5.5 cm (mean, 1.9 cm). The percentage necrosis in all 14 ranged 0–40%, with 8 showing no necrosis (mean, 8.6%). One of the 14 patients presented with metastatic disease (regional nodes and both lungs). Two (2/14, 14%) had recurrences: one distant-only, one distant and local. Both patients with recurrences died of disease; the remaining 12 were alive at the time of this report with no evidence of disease at last follow-up (mean length of follow-up, 5.9 years; range, 2.0–10.1 years).

Discussion

In our study, the 14 patients who did not have preoperative imaging were more likely to have classic-type histology tumors ($n=12/14$, 86%) than proximal histology ($n=2/14$, 14%). Those tumors were also smaller (mean maximum diameter 1.9 cm) than the 15 with preoperative imaging (mean maximum diameter 6.0 cm) and arose in sites easily amenable to surgical resection (10 were located in the extremities). Such tumors are likely to be resected without the need for anatomical localization with imaging, and in these cases the surgeon might expect benign disease. Two of the 14 patients (14%) without preoperative imaging presented with metastatic disease compared with 6 of the 15 (40%) with preoperative imaging. Among the 14 patients without preoperative imaging, only the two who presented with metastatic

disease died of disease, compared to 9 of the 15 (60%) with preoperative imaging. Additionally, the 15 patients with preoperative imaging were more likely to have proximal histology ($n=11/15$, 73%) tumors that were located in axial sites (head and neck, $n=3$; trunk, $n=4$). Although the majority of these 15 patients had proximal histology tumors, among the 8 with extremity tumors, there were equal numbers of classic ($n=4$) and proximal ($n=4$) histology. This finding illustrates the potentially confusing terminology used to histologically classify these tumors because proximal histological-type tumors can arise in distal anatomical sites. Although the proximal type of epithelioid sarcoma is reportedly more common in older adults than in children, we found no substantial difference in age at diagnosis between these histological groups [4]. Similar to prior reports, patients in our study with tumors having proximal pathological features were more likely to have metastatic disease at diagnosis; among the 15 patients with preoperative imaging, metastases were present in 6 of 11 with proximal features vs. 0 of 4 with classic-type epithelioid sarcoma. Tumor recurrence was common in both histological types, occurring in 80% of all 15 patients — 9 of 11 (91%) with proximal-type tumors (1 local recurrence only, 1 local and distant, 7 distant recurrence only) and 3 of 4 (75%) with classic tumor features (all 3 distant recurrence only).

Superficial epithelioid sarcomas have been reported to present as solitary or multiple firm nodules that are elevated above the skin surface. Deeply seated tumors are described as larger and less well-defined, and often they manifest as a lumpy, multinodular mass that is firmly attached to tendons, the tendon sheath, or fascial structures [8]. Deeply seated tumors often grow along the neurovascular bundle and encase large vessels. In our study, among 8 tumors that encased ($n=5$) or abutted ($n=3$) the neurovascular bundle, 6 were classified as deep. However in contrast to prior reports, we found that the majority of tumors, whether they were deep or superficial, had lobulated margins. Of the two tumors with smooth margins, one was classified as deep and the other as superficial. The reason for the discrepancy between our findings and prior reports is not clear but might be partly from variability in the local surgeons' assessment of tumor depth in contrast to the strict criteria used during central surgical review in our study.

In our study, all patients underwent lymph node sampling, and nodal involvement was present in 33% (5/15) of the patients with preoperative imaging. Although our sample size is small when nodal involvement was present (4/4, 100%). On imaging, involved nodes were sometimes larger than the primary tumor, and nodal necrosis was present in all four patients with biopsy-proven nodal involvement. However, we also had four false-positives for nodal involvement by imaging. Our findings are in line with prior reports and underscore the importance of lymph node sampling for accurate staging of these patients [10]. These findings also suggest that perhaps lymph node biopsies could be limited to patients with imaging findings suggestive of nodal involvement, but this needs to be validated in larger studies. Interestingly, in our cohort the diagnosis of epithelioid sarcoma was made in three patients by lymph node biopsy, and the primary tumor site was only discovered after lymph node sampling. Additionally, we found good agreement between the imaging and pathological estimates of percentage primary tumor necrosis. This is somewhat surprising but also reassuring given that pathological estimates were based on histological samples while imaging estimates were based on the entire tumor volume. This finding is important

because previous investigators have found that an increase in the amount of primary tumor necrosis is associated with a poorer prognosis [2-4, 17, 19].

Consistent with prior reports, peritumoral edema was a common imaging finding in our study [7, 11]. We found that all 10 tumors imaged by MRI had evidence of surrounding edema that was mild in 5 patients and marked in the remainder. It is possible that, at least in some cases, the edema contained tumor cells. Although our cohort is small, we found no apparent association between proximal or classic histology and degree of surrounding edema. In their report of eight people with epithelioid sarcoma, Hanna and colleagues [11] found peritumoral edema in six cases and categorized the edema as massive in two. Those investigators did not further classify the tumors as having proximal or classic pathological features. Tateishi et al. [7] reported that among 16 people with proximal-type epithelioid sarcoma, surrounding edema and infiltrative margins were common features, but they did not provide the incidence of this finding.

We also found that tumor margins were infiltrative in the majority of cases (10/14, 71%), including three of the four with classic pathological features. In two cases, we found satellite tumor nodules vs. lymph nodes in close proximity to the primary tumor. These nodules were not biopsied and might have represented local/regional soft-tissue tumor deposits, which are known to occur in epithelioid sarcoma [8, 10]. Taken together, these findings suggest that epithelioid sarcoma, whether it has proximal or classic pathological features, is generally associated with imaging evidence of surrounding inflammation and infiltration of adjacent structures. These imaging features are in keeping with the growth pattern of this tumor, which tends to spread along fascial planes, aponeuroses and tendon sheaths [1-4, 20].

Our study has several limitations. Because epithelioid sarcoma is a rare tumor, our sample size is somewhat small. However our study is unique because it focuses on a younger population than prior studies and includes imaging prospectively obtained on modern-generation MR and CT scanners that was centrally reviewed by two pediatric radiologists with years of clinical experience. Because of the lack of correlative or conformational imaging, such as ultrasound and diffusion-weighted MRI, we made several assumptions regarding the presence of necrosis and hemorrhage, although we used strict criteria (described in the methods) to ensure consistency.

Conclusion

Our findings agree with those of others who have described the imaging features of epithelioid sarcoma as a frequently lobulated, partially or predominantly necrotic mass with poorly defined margins and surrounding edema. Contrary to prior reports, we found that the proximal pathological type occurs in a similar age group as the classic histology, although this finding might have been a result of our small sample size. We found good agreement between the pathological and imaging assessments of primary tumor necrosis, which is common in epithelioid sarcoma and has prognostic significance [4, 6, 21]. Because epithelioid sarcoma spreads along fascial planes and to local/regional nodal basins, we recommend imaging the entire involved extremity or adjacent body cavities to determine tumor extent. Pre- and post-contrast-enhanced MRI is the preferred modality for assessing extremity

tumors, whereas either contrast-enhanced CT or MRI can be used for imaging tumors arising in the trunk. When nodal necrosis is present, there is a high likelihood of tumor involvement and these children might present with involved nodes that are larger than the primary tumor. However, enlarged lymph nodes cannot be presumed to be malignant, and lymph node sampling is essential for accurate staging. It is important to note that in our study nodal metastases were not identified in patients without imaging evidence of pathological lymphadenopathy, calling into question whether routine lymph node sampling is necessary in all patients. Confirmation of this finding in a larger population of patients could potentially limit the need for lymph node biopsies to those with abnormal lymph nodes by imaging. Additional studies are needed to verify our findings.

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Fig. 1.

Hematoxylin and eosin histology specimens demonstrate variants of epithelioid sarcoma. **a** Classic epithelioid sarcoma (60X). The lesion comprises sheets of epithelial cells surrounding a central area of coagulative necrosis. **b** Classic epithelioid sarcoma (200X). Some lesions, such as this, have a deceptively low-grade, benign appearance, and contain elongate cells resembling epithelioid macrophages. Note the central area of coagulative necrosis and hemorrhage. This can lead to a mistaken diagnosis of granulomatous inflammation. **c** The proximal variant contains larger cells with features of malignant rhabdoid tumor (eccentric nuclei, prominent nucleoli, moderately abundant cytoplasm, and cytoplasmic inclusions). In this illustration (180X), the central cells exhibit rhabdoid features

Fig. 2.

Epithelioid sarcoma of the foot in an 11-year-old girl (Patient 15, Table 3). **a** Axial proton-density MR image (repetition time/echo time [TR/TE] = 3,630/33 ms) demonstrates infiltrative tumor between the first and second metatarsals (*curved arrows*) with evidence of direct bone invasion (*straight arrow*). **b** Sagittal short tau inversion recovery (STIR; TR/TE=3,700/15 ms) MR image shows the epicenter of the soft-tissue tumor (*arrows*) surrounding the first metatarsal. Note surrounding edema, a common feature of epithelioid sarcoma. **c** Axial contrast-enhanced CT image shows involved inguinal node (*arrow*) that was larger than the primary tumor

Fig. 3.

Epithelioid sarcoma of the foot in a 22-year-old woman (Patient 14, Table 3). **a** Sagittal T1-W (repetition time/echo time [TR/TE] = 589.0/9.6 ms) non-contrast-enhanced MR image shows that the deeply seated tumor (*T*) tracking along the aponeurosis is isointense to muscle. **b** Coronal contrast-enhanced T1-W MR image (TR/TE 600.0/7.1 ms) shows the poorly defined, predominantly necrotic tumor (*T*). These are common features of epithelioid sarcoma

Fig. 4. Epithelioid sarcoma in a 14-year-old girl with primary site in the wrist (Patient 8, Table 3). **a** Coronal T1-W (repetition time/echo time [TR/TE] = 400.0/16.8 ms) contrast-enhanced MR image shows the partially necrotic tumor (*T*) with marked surrounding edema. **b** Sagittal T1-W (TR/TE=601.1/16.8 ms) contrast-enhanced MR image shows the poorly defined infiltrative tumor (*T*) tracking along the aponeurosis (*arrow*)

Fig. 5. Epithelioid sarcoma in a 13-year-old girl with a pelvic primary site (Patient 6, Table 3). Axial contrast-enhanced CT image shows large pelvic primary tumor (*straight arrows*) and enlarged metastatic bilateral iliac nodes (*curved arrows*)

Fig. 6. Epithelioid sarcoma in a 24-year-old man with calf primary site (Patient 11, Table 3). **a** Sagittal contrast-enhanced T1-W (repetition time/echo time [TR/TE] = 527/15 ms) MR image shows the calf primary tumor (*T*) and small satellite nodule (arrow) that could represent tumor spread along the fascial plane. Note the infiltrative tumor margins and surrounding edema, common features in epithelioid sarcoma

Table 1

Demographics, primary tumor sites and histology of 14 epithelioid sarcoma subjects without preoperative imaging and 15 with preoperative imaging

Characteristic	With preoperative imaging		Without preoperative imaging		Combined	
Histology	Classic	Proximal	Classic	Proximal	Classic	Proximal
Number of subjects	<i>n</i> =4	<i>n</i> =11	<i>n</i> =12	<i>n</i> =2	<i>n</i> =16	<i>n</i> =13
Age at diagnosis (yrs)						
Median	20.5	11.7	12.7	14.9	13.5	13.0
Range	13.9–24.8	6.5–22.5	2.5–20.7	13.3–16.6	2.5–24.8	6.5–22.5
Gender ^a						
Male	2	4	4	1	6	5
Female	2	7	8	1	10	8
Race ^a						
White	3	9	10	2	13	11
Black	0	2	1	0	1	2
Unknown	1	0	1	0	2	0
Anatomical sites ^a						
Head and neck						
Head		1	1		1	1
Neck		2				2
Limb girdle						
Shoulder			1		1	
Hip						
Trunk						
Chest wall		1		1		2
Abdominal wall				1		1
Retroperitoneal		1				1
Pelvis		1				1
Perineum		1				1
Extremity						
Hand	1	2	7		8	2
Lower arm			3		3	
Upper arm						
Foot	1	1			1	1
Lower leg	2	1			2	1
Thigh						

^aNumber

yrs years

Table 2

MRI and CT features of 15 epithelioid sarcomas

Imaging feature	MRI	CT	Total
	n=10 (%)	n=5 (%)	n=15 (%)
Tumor origin			
Muscle	3 (30)	2 (40)	5 (33)
Fat	2 (20)	1 (20)	3 (20)
Indeterminate	5 (50)	2 (40)	7 (47)
Tumor contour			
Smooth	1 (10)	1 (20)	2 (13)
Lobulated	9 (90)	4 (80)	13 (87)
Margins^a		(n=4)	(n=14)
Sharp	4 (40)	0 (0)	4 (29)
Infiltrative	6 (60)	4 (100)	10 (71)
Surrounding edema	10 (100)	N/A	
Minimal	5 (50)	N/A	
Moderate	0 (0)	N/A	
Marked	5 (50)	N/A	
Predominant T1-W signal intensity	(n=10)		
Hypointense	0 (0)	N/A	
Isointense	6 (60)	N/A	
Hyperintense	3 (30)	N/A	
Mixed	1 (10)	N/A	
Predominant T2-W/STIR signal intensity		N/A	
Hypointense	0 (0)	N/A	
Isointense	0 (0)	N/A	
Hyperintense	10 (100)	N/A	
Mixed	0 (0)	N/A	
Hemorrhage	4 (40)	N/A	
Calcifications	N/A	0 (0)	
Enhancement pattern^a		(n=4)	(n=14)
Homogeneous	3 (30)	1 (25)	4 (30)
Heterogeneous (partial necrosis)	5 (50)	2 (50)	7 (50)
Peripheral (predominantly necrotic)	2 (20)	1 (25)	3 (20)
Enhancement intensity^a		(n=4)	(n=14)
Mild	2 (20)	3 (75)	5 (36)
Moderate	2 (20)	1 (25)	3 (21)
Intense	6 (60)	0 (0)	6 (43)
Regional abnormal nodes	(n=5 assessed)	(n=5 assessed)	(n=10)
Present	3 (60)	5 (100)	8 (80)
Absent	1 (20)	0 (0)	1 (10)

Imaging feature	MRI	CT	Total
	n=10 (%)	n=5 (%)	n=15 (%)
Indeterminate	1 (20)	0 (0)	1 (10)

N/A not applicable, *STIR* short tau inversion recovery

^a Could not assess margins, enhancement intensity or enhancement pattern on one CT because it was performed without contrast agent

Table 3

Anatomical site, tumor size, depth, neurovascular involvement, pathological classification, percentage primary tumor necrosis estimated on pathology and imaging, presence of metastatic disease at baseline, and recurrence site of 15 children and young adults with epithelioid sarcoma

Patient	Primary site	Largest tumor diameter	Tumor depth at surgery	Neurovascular bundle involvement on imaging	Pathology classification (proximal /classic)	% primary tumor necrosis on pathology	% primary tumor necrosis on imaging	Metastatic disease site at diagnosis	Recurrence site
1	Head	1.5 cm	Superficial	Not abutting	Proximal	10	0	None	None
2	Neck	2.4 cm	Deep	Not abutting	Proximal	80	N/A	Lungs	Lungs
3	Neck	4.6 cm	Deep	Encased	Proximal	20	10	None	Lepto- meningeal
4	Chest wall	3.1 cm	Deep	Not abutting	Proximal	30	N/A	None	Local, lung, pleura
5	Retroperitoneal	19.0 cm	Deep	Encased	Proximal	Unknown ^a	30	Bone, liver, peritoneum, nodal	Liver
6	Pelvis	10.0 cm	Deep	Encased	Proximal	Unknown ^a	N/A	Nodal, liver	Brain
7	Perineum	1.6 cm	Deep	Not abutting	Proximal	10	0	None	Local
8	Wrist	3.6 cm	Superficial	Encased	Classic	30	10	None	Pleura, lung
9	Hand	1.2 cm	Superficial	Not abutting	Proximal	0	0	None	None
10	Hand	3.0 cm	Deep	Not abutting	Proximal	30	0	Nodal, Lungs	Lung
11	Lower leg	6.2 cm	Deep Deep	Abutting	Classic	10	40	None	Lung
12	Lower leg	4.5 cm	superficial	Not abutting	Proximal	Unknown ^a	20	Nodal	Nodal
13	Lower leg	13.5 cm	Deep	Abutting	Classic	10	20	None	None
14	Foot	9.3 cm	Superficial	Abutting	Classic	70	80	None	Nodal, lung, subcutaneous
15	Foot	5.9 cm	Deep	Encased	Proximal	Unknown ^a	10	Nodal	Nodal, lung

^aDiagnosis was either made on lymph node biopsy ($n=3$) or percentage necrosis of the primary tumor was not recorded ($n=1$)

N/A not applicable because CT image quality was inadequate