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Research Paper

Surgical management and outcome of Extra-adrenal myelolipomas at unusual locations: A report of 11 cases in a single center

Jiashi Cao [a,b,1], Xing Huang [b,1], Na Cui [c,1], Xiang Wang [d], Chaoqun You [b,e], Xiangzhi Ni [b], Xin Gao [b,*], Jing Wang [b,*], Tielong Liu [b,*]

[a] Department of Orthopedics, No. 455 Hospital of the Chinese People's Liberation Army, The Navy Medical University, No. 338 Huaihai West Road, Shanghai 200052, China
[b] Department of Orthopaedic Oncology, Changzheng Hospital of the Navy Medical University, No. 415 Fengyang Road, Shanghai 200003, China
[c] Department of Pathology, Changzheng Hospital of the Navy Medical University, No. 415 Fengyang Road, Shanghai 200003, China
[d] Department of Radiology, Changzheng Hospital of the Navy Medical University, No. 415 Fengyang Road, Shanghai 200003, China
[e] Clinical Medical College of Weifang Medical University, No.7166 Baotong West Street, Weifang, Shandong 261000, China

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ABSTRACT

Purpose: Extra-adrenal myelolipomas (EAMs) are rare benign tumors composed of both mature adipose and hematopoietic tissues with unclear etiology. There have been only sporadic case reports about the clinical characteristics and management of EAMs. Here we present our experience and practice in the clinical diagnosis and treatment of 11 consecutive patients with EAMs.

Method: We retrospectively reviewed 11 consecutive patients, who received surgeries in our department and were confirmed as having EAMs by postoperative histopathology from April 2016 to December 2021. Clinical information and follow-up data of all patients were collected and analyzed afterwards.

Results: Of the 11 EAM patients (7 male and 4 female) with a mean age of 47.6 years, 3 were asymptomatic and 8 were symptomatic with a mean symptom duration of 6.07 months. EAMs were found in the thoracic spine in 4 cases, paravertebral mediastinal regions in 3 cases, ilium in 2 cases, humerus in 1 case, and rib in 1 case. All patients were initially misdiagnosed as other tumors by radiologists. All 11 patients received gross total excision or curettage with a mean intraoperative blood loss of 781.82 ± 1143.3 ml and a mean operation duration of 180.91 ± 98.41 min. Patients' Frankel scores and Karnofsky Performance Status score were improved or at least preserved postoperatively. No significant complications occurred postoperatively. All the 11 patients survived, and no local recurrence or distant metastasis occurred during the mean follow-up period of 42.0 months.

Conclusion: The surgical outcome and prognosis of EAMs are excellent and surgery can serve as the method of radical treatment.

1. Introduction

Myelolipoma is a rare benign and nonfunctioning tumor composed of hematopoietic cells and mature adipose tissue, typically occurring in the adrenal glands with an incidence of approximately 0.08–0.4% according to autopsy studies [1–4]. It was firstly described by Edgar von Gierke in 1905, and then was entitled as "myelolipoma" by Charles Oberling in 1929 [5,6]. Extra-adrenal myelolipoma (EAM) is even rarer, accounting for about 15% of all myelolipomas, and the predilection sites include the presacral (40%), peritoneal (20%), and thoracic (15%) cavities [2,7]. They are more commonly reported in women aged between the fifth and seventh decade with a female/male ratio of 2:1 [3,8]. However, fewer than 10 cases of EAMs in the spinal or intraosseous regions had been described in sporadic case reports by 2021 [2,3,9–13].

At present, there is no consensus over the etiology and pathogenesis of EAMs. Due to the lack of specific imaging features and clinical manifestations, preoperative diagnosis of EAMs remains a clinical challenge. Given the tumor's rarity and a lack of large case series, the standard treatment and long-term clinical follow-up outcome of EAMs remain unclear. Herein, we make a summary of our experiences and practice in

Abbreviations: EAMs, Extra-adrenal myelolipoma.

* Corresponding authors.
E-mail addresses: czyygaoxin@smmu.edu.cn (X. Gao), wangj0415@163.com (J. Wang), liutielongvip@163.com (T. Liu).

[1] All contributed equally to this work, and all the first three authors are regarded as co-first authors.

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the management of 11 consecutive patients with EAMs, hoping that it could provide more useful data regarding the clinical features and management strategies of this rare benign tumor in the spinal and intraosseous regions.

2. Materials and methods

2.1. Patients

This study retrospectively reviewed all patients who underwent surgeries and were pathologically confirmed as having EAMs of the spinal and intraosseous regions in our institution from April 2016 to December 2021. All patients' general information, clinical and imaging manifestations, operation details, pathological findings, and follow-up outcomes were collected. All patients were followed up regularly after surgeries. Follow-up observation ended at the date of patient death or in February 2022. Informed consent was obtained from all participating patients before initiation of the study. The study procedures were conducted according to the principles of the Declaration of Helsinki and approved by the ethics committee of our hospital.

2.2. Imaging assessment

Imaging examinations mainly included plain radiographs, CT and MRI with gadolinium-contrast enhancement. Reconstructed 3D CT or CTA would be performed in patients with fractures. Imaging diagnosis was performed by two senior musculoskeletal radiologists.

2.3. Surgery

For patients with spinal or paravertebral involvement, posterior middle incisions were made in a prone position. In remaining cases, the posture and incision area depended on the location of the lesion. Tumors were all removed as completely as possible. Tumor resection and protection of the surrounding structures were assisted by using the binocular magnifier. Spinal reconstruction was implemented by using the screw and rod system or in-situ lamina replantation with tiny titanium plate fixation according to the specific location of the lesion. Bone defect-filling materials mainly included the titanium mesh, artificial vertebral body, bone cement and bone allograft.

3. Results

3.1. General information

The general information of the 11 patients included in this study are demonstrated in Table 1. They aged from 13 to 69 years with a mean of 47.55 ± 20.76 and a median of 55 years with a male-female ratio of 7:4. They all received surgery and were diagnosed with myelolipoma by postoperative histopathology. Of them, 8 patients (72.73%) presented the clinical symptoms with a mean symptom duration of 6.07 ± 8.24 months, including pain or discomfort, limb numbness or weakness (*Case 3*, Fig. 1), and pathological fracture accompanied with spinal kyphosis (*Case 4*, Fig. 2), and the remaining 3 patients were asymptomatic. The mean duration of symptoms was 6.07 ± 8.24 months (range: 1 week to 24 months). The EAMs in these patients were mainly distributed in the thoracic spine (n = 7) and intraosseous regions (n = 4). The former included two cases involving the vertebral body (*Case 1 and 4*), one involving the thoracic spinal epidural area (*Case 3*, Fig. 1), and four involving the paravertebral mediastinal regions (*Case 2, 5, 6 and 7*). Intraosseous EAMs were found in the left (*Case 8*) and right (*Case 9*) ilium, right humerus (*Case 10*) and the right 8th posterior rib (*Case 11*).

3.2. Imaging assessment

Of the 11 patients, 8 underwent MRI scan and 9 received CT exams

Table 1
Clinical data of patients with spinal and intraosseous EAMs.

No.	Age/ Sex	Preoperative status			Location	Tumor Size (cm)	KPS/F-S pre	Treatment				Follow-up			
		Symptoms	DOS (months)	Accompanied disease				Operation	Time of op (min)	Blood loss (ml)	Complication	KPS/F-S post	Follow-up (months)	LR/ meta	Last status
1	62/M	None	NA	DM	TS	7	80/D	GTE + TSS + BC	240	400	None	90/E	18	None	Alive
2	58/F	Pain	24	HTN	TPR/PM	2.2	81/D	GTE + TSS	170	500	None	91/E	70	None	Alive
3	13/M	Numbness, LW	0.33	None	TS	4	70/C	GTE + LP + TM	190	400	None	92/E	46	None	Alive
4	13/M	Pain, SK	12	None	TS	3.6	80/E	GTE + TSS + AVB + BA	195	500	None	93/E	42	None	Alive
5	69/M	Discomfort	2	DM, HTN	TPR/PM	3	80/E	GTE + TSS	230	1500	None	94/E	3	None	Alive
6	61/F	None	NA	DM	TPR/PM	2.8	90/E	GTE + TSS	180	200	None	95/E	40	None	Alive
7	55/M	None	NA	DM	TPR/PM	2.6	90/E	GTE + TSS	220	800	None	96/E	57	None	Alive
8	25/F	Pain	0.23	None	Ilium	3.1	80/E	Curettage + BA	55	200	None	97/E	48	None	Alive
9	46/M	Pain	3	None	Ilium	13.2	80/E	Curettage + BA	390	4000	None	98/E	44	None	Alive
10	66/F	Numbness	6	HTN, HT	Humerus	2	90/E	Curettage + BA	50	50	None	99/E	57	None	Alive
11	55/M	Discomfort	1	HTN	Rib	4.4	90/E	GTE	70	50	None	100/E	37	None	Alive

DOS: duration of symptom; KPS/F-S pre: preoperative Karnofsky Performance Status scores/Frankel scores; Time of op: time of operation; KPS/F-S post: postoperative Karnofsky Performance Status scores/Frankel scores; LR/meta: local recurrence/metastasis; M: male; F: female; NA: not available; DM: diabetes mellitus; HTN: hypertension; HT: hypothyroidism; TS: thoracic spine; TPR/PM: thoracic paravertebral region or posterior mediastinum; GTE: gross total excision; TSS: titanium screw-rod systems; BC: bone cement; LP: laminoplasty; TM: titanium microplates; AVB: artificial vertebral body; BA: bone allograft.

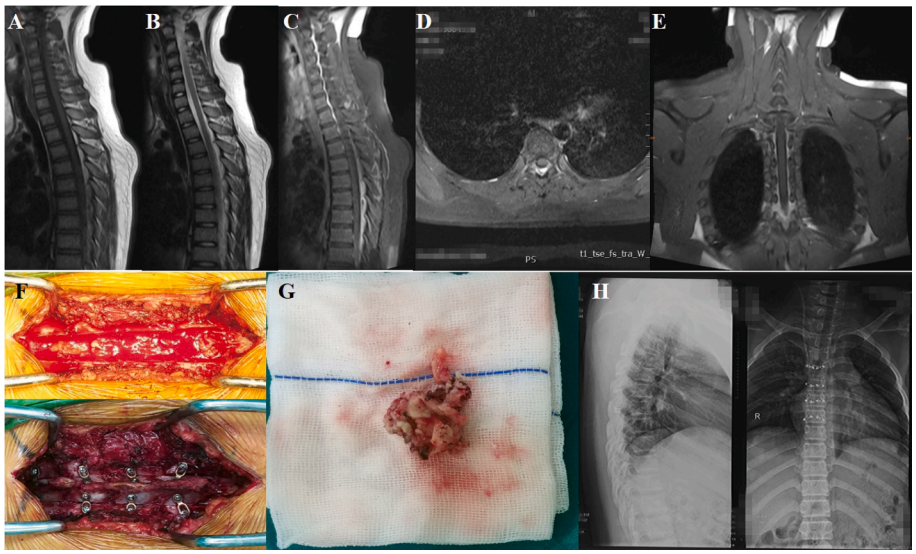

Fig. 1. A 13-year-old boy with a thoracic spinal epidural EAM. Preoperative MRI scan consisted of (A) T1 sagittal, (B) T2 sagittal, (C) T1 + C sagittal, (D) T1 + C axial, and (E) T1 + C coronal images, showing a strip-like lesion growing dorsally within the spinal canal at T4-T7 with the characteristics of T1 hyperintense, T2 hyperintense, and enhancement changes on T1 + C; (F) Laminoplasty was performed after resection of the lesion; (G) Completely resected lesion; (H) Postoperative X-ray showed decompression and instrumentation.

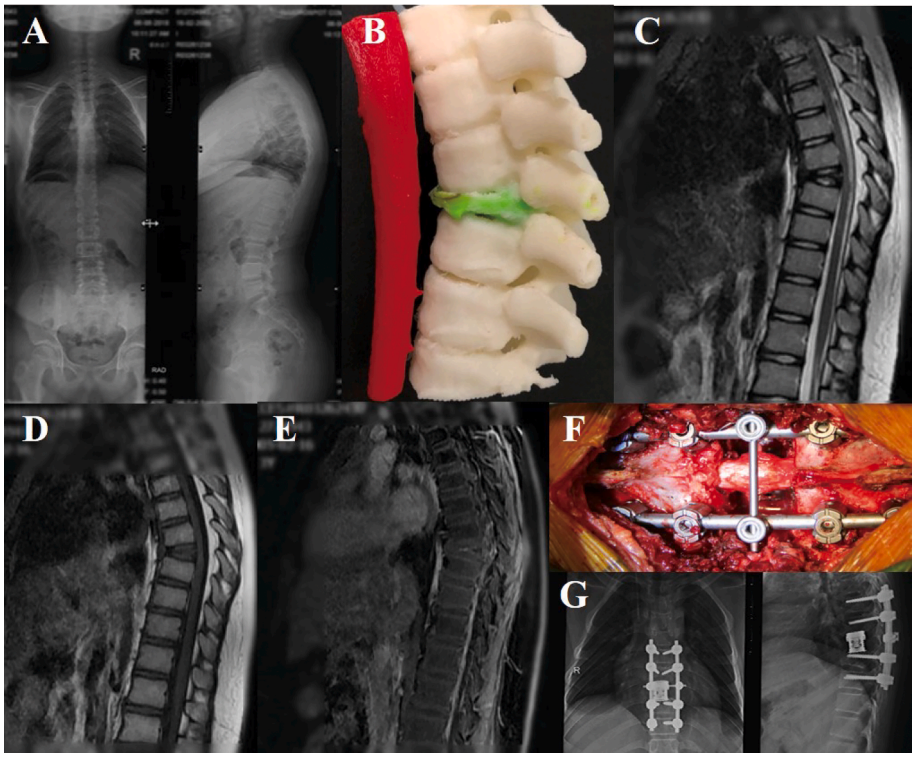

Fig. 2. A 13-year-old boy (A) X-ray showing the compression fracture of T8 before surgery; (B-E) Preoperative sagittal 3D CT&MRI scan (T1, T2, T1 + C) showing a compression fracture in the vertebral body of T8; (F) Intraoperative picture showing total spondylectomy and instrumentation; (G) Postoperative X-ray showing decompression and instrumentation.

for review. The imaging characteristics of the 11 patients are presented in Table 2. MRI and CT showed that most of the lesions appeared as localized well-defined soft tissue masses in an oval or round shape, except for *Case 4 and 8* with blur margins. The mean diameter of the masses was 4.35 ± 3.24 cm. Bone destruction or pathological changes of bone were observed in 8 cases, but not in the 3 patients with paravertebral mediastinal EAMs. In most cases, high signal intensities were presented on both T1- and T2-weighted sequences. Varying degrees of enhancement were displayed in 7 of the 8 MRI exams and 4 of the 9 CT exams. It is noteworthy that the initial preoperative impression given to the radiologists was not EAM in all cases. Four cases were misdiagnosed as malignant tumors including liposarcoma in *Case 1 and 9*, solitary plasmacytoma in *Case 4* (Fig. 2), malignant bone tumor of unknown tissue origin in *Case 10*. One lesion in *Case 11* confined to the 8th posterior rib demonstrated expansive growth, which was considered as giant cell tumor of bone. Although the rest were classified as benign, they originated in various tissues, including neurogenic (*Case 2 and 5*), cartilaginous (*Case 8*), and adipose (*Case 3 and 7*).

3.3. Treatment details

All surgical procedures were all performed by senior surgeons. All

Table 2
Imaging characteristics with spinal and intraosseous EAMs.

No.	MRI						CT				Imaging diagnosis
	Margin	Bone destruction	T1WI	T2WI	Enhance change	Morphology	Margin	Bone destruction	Enhance change	Morphology	
1	Clear	N	High-low mixed	High-low mixed	Moderate	Massive	Clear	N	N	Fatty density	Liposarcoma
2	Clear	Y	Slightly high	Slightly high	Moderate	Round-like	\	\	\	\	Neurogenic tumor
3	Clear	N	High	High	Moderate	Strip abnormal signal		\	\	\	Angiolipoma
4	Blur	Y	High	High	Significant	small patchy opacity	Blur	Y	Significant	small patchy opacity	SP
5	Clear	N	Slightly high	Slightly high	Significant	Round-like	Clear	N	Slight-moderate	Round-like	Neurogenic tumor
6	Clear	N	Equal	Slightly high	Moderate	Oval mass	Clear	N	N	Cystic expansion with water density	Cystic mass
7	Clear	Y	High	High	Slight	Oval mass	Clear	Y	Moderate	Fatty density	Lipoma
8	Blur	N	Equal-low mixed	Equal-low mixed	None	Round-like	Blur	N	N	Round-like	cartilaginous tumor
9	\	\	\	\	\	\	Clear	N	N	Fatty density	Liposarcoma
10	\		\	\	\	\	Clear	N	Moderate	Flaky	Malignant tumor
11	\	\	\	\	\	\	Clear	Y	N	Mass with localized expansive growth	GCT

MRI: Magnetic resonance imaging; CT: computed tomography; T1WI: the signal intensity of T1WI; T2WI: signal intensity of T2WI; N: none; Y: yes; SP: solitary plasmacytoma; GCT: giant cell tumor of bone.

patients received gross total excision or curettage, including spinal reconstruction with the titanium screw-rod systems in 6 cases, laminoplasty with titanium microplates in one case, and no internal fixation in the remaining cases. The bone defects were repaired by the artificial vertebral body filled with bone allograft in *Case 4* (Fig. 2), bone allograft alone in *Case 8 to 11*, and bone cement alone in *Case 1*. The mean intraoperative blood loss was 781.82 ± 1143.3 (50–4000) ml. The mean duration of surgery was 180.91 ± 98.41 (50–390) min. *Case 5 and 9* received intraoperative blood transfusion due to respective 1500 ml and 4000 ml blood loss during operation. Although preoperative imaging demonstrated vertebral body involvement in *Case 2 and 6*, it was not detected during surgery. No significant postoperative complication occurred. Light microscopy of the hematoxylin and eosin (H&E)-stained sections revealed adipose tissues and hematopoietic components in the tumors (Fig. 3A–C). Frankel scores of patients with spinal EAMs were at least raised one level or preserved postoperatively. Symptomatic patients were all relieved with the promotion of life quality, as presented by the increased postoperative Karnofsky Performance Status scores. All patients received neither radiotherapy nor chemotherapy after surgeries.

3.4. Follow-up

All patients were followed up for 1 and 3 months routinely after surgeries, with an interval of 3 months in the first year, every 6 months in the second year and yearly afterwards. The average follow-up period was 41.9 months (range from 3 to 70 months). All the patients survived. Neither local recurrence nor distant metastasis was observed in any patient during follow-up (Table 1).

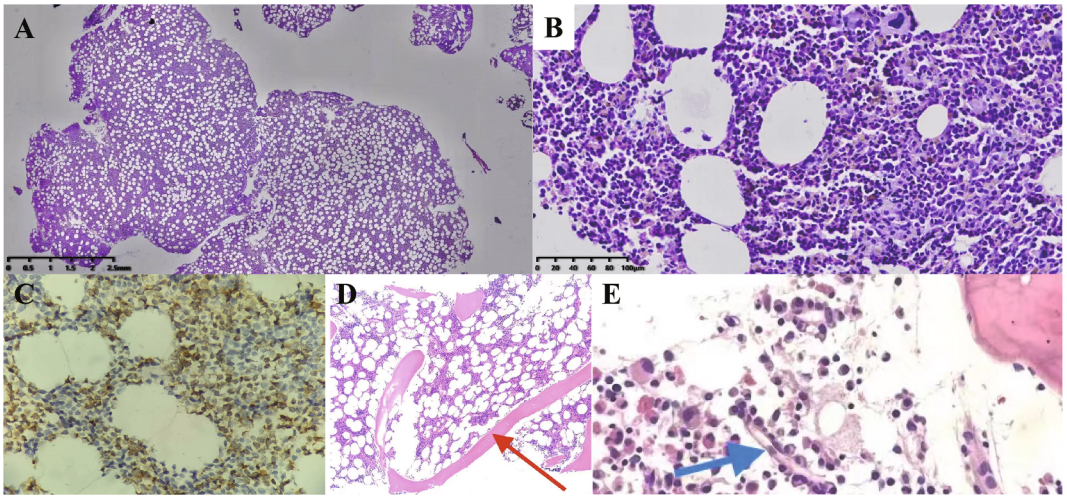

Fig. 3. Histopathologic examination of EAM (A-C) and normal bone marrow (D-E). (A) At low magnification (40 ×), the tumor showed clear boundaries; (B) At high magnification (400 ×), the tumor consisted of scattered mature adipocytes and three lines of hematopoietic cells; (C) Myeloid cells with MPO positive expression in hematopoietic tissues (Vision method); Trabecular bone (D, red arrow) and thin-walled sinuses (E, blue arrow) are seen in the normal bone marrow. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4. Discussion

Myelolipoma is a rare benign tumor composed of nature adipose cells and a mixed proportion of myeloid and erythroid elements, usually occurring in the adrenal gland without endocrine function [2,3]. As reported in many studies [2,3,8], EAMs have a woman predominance with the female to male ratio of 2:1, and are susceptible to the ages from 50 to 70 years. However, Cheng shen et al. reported that EAMs mainly occurred in males between 50 and 70 years of age with the male to female ratio ranging from 2:1 to 1:1 [5]. Consistently, our study demonstrated that the male to female ratio was 1.75:1 (M: F = 7: 4). Most EAMs were found in the presacral region or peritoneal cavities and rarely in other locations [2,7]. As presented in Table 3, our research on Pubmed (*http://www.ncbi.nlm.nih.gov/pubmed/*) only retrieved 8 EAMs in the spine (n = 2) or intraosseous region (n = 6) [2,3,9–13]. Of the 2 EAMs in the spine, one was in the thoracic spinal canal [13] and the other in the lumbar vertebral body [3]. The 6 EAMs in the intraosseous regions involved the mandible [9], rib [10], acetabulum [11] and femur (n = 3) [2,11,12]. To the best of our knowledge, this study reports the largest case series of the spinal and intraosseous EAMs so far even though 4 cases of parathoracic EAMs were not included, which can also be classified as mediastinal EAMs. It is remarkable that EAMs were observed in the thoracic vertebral body (n = 2) and the humerus (n = 1) in our series, which are all the first report in the English literature. Furthermore, we provide the second report of EAMs located in the thoracic spinal canal, rib and ilium (n = 2).

The exact etiology of EAMs remains unclear, although several hypotheses have been put forward to explain the pathogenesis. The more accepted explanation is metaplasia in reticuloendothelial cells, caused by various stimuli including infection, stress, obesity, hypertension, diabetes and Cushing's disease[14]. Several studies believe that embolization of the bone marrow tissue or the metaplastic alterations of embryonic primitive mesenchymal cells is also the possible cause of EAMs [3,15,16]. In addition, chromosomal translocations have been identified in myelolipoma cells, which are also observed in lipomatous neoplasms [5,17]. Most thoracic EAMs tend to attach to the spinal vertebral bodies, considering that microfractures may cause hematopoietic tissue to project from the spinal vertebral bodies to the paravertebral spaces. The ectopic hematopoietic tissue may contain stem cells, which would be the origin of EAMs [18].

EAMs are usually asymptomatic and found by chance, unless the mass effect generated by the tumor's growing size causes compression on the surrounding tissues or organs [3]. But the symptoms lack specificity and vary with different tumor locations. As previously mentioned in this study, 8 (72.73%) of the 11 cases were symptomatic, including local pain in 5 cases (45.45%) and discomfort in 3 cases (27.27%). Of them, *Case 4* was also accompanied with pathologic fracture and thoracic vertebral kyphosis (Fig. 2). Neurological defects were observed in a 13-year-old male patient with a thoracic spinal epidural EAM (*Case 3,* Fig. 1), who presented numbness and limb weakness of the right lower extremity (Frankel score = 4) (Table 1). Through review of the literature, Cheng Shen et al. summed up the clinical characteristics of thoracic EAMs in 36 patients, of whom 20 (55.56%) were asymptomatic at their first visit, 9 (25%) had cough and 6 (16.67%) had fever [5]. Other symptoms such as urinary retention or sciatic pain in presacral lesions, gait disturbance in intraspinal lesions have also been also reported [5]. Acute hemorrhage, as the most significant complication, could occur in large myelolipomas [19].

Imaging examination plays a critical role in establishing the diagnosis of EAMs or excluding malignancy of the tumors. EAMs typically occur in solitary forms depicted as an oval or round shape with clear boundaries. However, the tumor boundary was obscure in 2 cases of our series, which misled the initial imaging diagnosis of the tumor. Generally, a low-attenuation area can be observed in EAM on the CT scan, and the diversity of CT densities could be explained by various proportions of the adipose and bone marrow tissues in EAM. It is of great importance to discern the predominant myeloid element with high-attenuation area in the fatty element with the low-attenuation area[20,21]. Littrell et al. [22] reported 11 patients with presacral EAMs and observed mild-to-moderate enhancement on CT imaging in all their patients. However, enhancement change was observed in only 4 (44.44%) of the 9 patients who underwent CT scan in our study, and the enhancement was significant in *Case 4*. On MRI, EAMs are relatively homogeneous with the characteristics of high-signal intensity in both T1- and T2-weighted sequence for mature adipose tissues. Given the low signal of the myeloid element on T1-weighted imaging and moderate signal on T2-weighted imaging, the adipose tissue can be detected easily on MRI through a fat saturation technique [21]. Most cases in our series

Table 3
Literature review for intraosseous and spinal EAMs.

No.	Author [ref.]	Age, sex	Symptoms	DOC (months)	Accompanied disease	Location	Tumor Size (cm)	Imaging diagnosis	Operation	Comp	Follow-up (months)	LR/meta	Last status
1	Chiarini L et al. [9]	NA, F	Mass formation	12	NA	Right mandible	NA	NA	Excision	NA	18	None	Alive
2	Wen J et al. [10]	18, M	None	NA	None	Rib	2	NA	Radical resection	None	24	None	Alive
3	Sundaram M et al. [11]	35, F	Pain	NA	None	the right acetabulum	4	FD	Curettage	NA	NA	NA	NA
4	Sundaram M et al. [11]	51, NA	Pain	NA	DM, DA, SF	proximal femur	NA	FD	Resection + PR	NA	NA	NA	NA
5	Papapietro N et al. [12]	80, M	Pain	NA	PC	proximal femur	5	NA	Curettage + BA	None	18	None	Alive
6	Sakai T et al. [2]	25, F	NA	120	CCH	Distal femur	20	OS	Observation	NA	24	NA	AWD
7	Omdal D et al. [13]	49, M	Numbness, GD, pain, IBI	6	None	TS	NA	NA	Piecemeal + LAM	NA	10	None	Alive
8	Rezaee H et al. [3]	62, M	Pain, limb weakness	156	NA	LS	7.6	NA	Piecemeal + TSS + BA	NA	3	NA	Alive

Ref.: references; Comp: Complication; LR/meta: local recurrence/metastasis; NA: not available; F; female; M: male; GD: gait disturbance; IBI: intermittent bladder incontinence; DM: diabetes mellitus; DA: degenerative arthritis; SF: stress fracture; PC: prostate cancer; CCH: congenital cytomegalovirus hydrocephalus; TS: thoracic spine; LS: lumbar spine; FD: fibrous dysplasia; OS: Osteosarcoma; PR: prosthetic replacement; BA: bone allograft; LAM: laminectomy; TSS: titanium screw-rod systems; AWD: alive with disease.

exhibited high signal intensities on T1- and T2-weighted sequences, while two patients (*Case 1 and 9*) presented mixed signal intensities on both T1- and T2-weighted sequences. Enhancement was typically moderate but 2 of the 8 cases with MRI exams showed mild enhancement and one had no enhancement. It has been also reported that calcification could be observed in very rare cases of EAMs [3,23].

Despite advances made in imaging techniques, it is still difficult for radiologists to make a differential diagnosis only based on radiology, including lipomas, liposarcomas, angiomyolipomas, teratomas and extramedullary hematopoiesis [2,3,24]. All 11 patients in our report were initially misdiagnosed as other tumors by radiologists. The high rate of misdiagnosis might be explained by the absence of specific imaging manifestations in EAMs, extensiveness of fat-containing lesions requiring differential diagnosis, and the rarity of EAMs, all of which may limit the correct diagnosis of EAMs, especially in radiologists with less experience. It is extremely difficult to establish a definitive diagnosis by imaging presentations alone [2,21]. Pathology remains the gold standard for the diagnosis of EAMs. Pathologically, typical EAMs are characterized by different forms of hematopoietic cells (erythroid cells, erythroid cells and megakaryocytes) mixed with mature adipocytes and rare bony trabeculae [1,25]. Similar features were also showed in our cases (Fig. 3A–C). Although morphology of EAMs is similar with that of the normal bone marrow tissue, the key point of identification between the two tissues is that the trabecular bone and thin-walled sinuses are commonly observed in normal bone marrow (Fig. 3D–E), but rare in EAMs. Malignant degeneration of EAMs has never been reported so far.

There is no consensus regarding the EAMs management [3,21]. Given the rarity of EAMs, there is limited knowledge about their natural history, long-term prognostic outcomes and treatment recommendations. Treatment of EAMs is either observational or surgical. Several factors should be taken into consideration comprehensively to determine whether surgery is indicated, including the general condition of the patient with or without symptoms, the risk of surgical intervention, and location and size of the tumor. In thoracic EAMs, quite a few studies suggest surgical therapy as the first option because the tumor has the capacity of continuous growth [5,26,27]. However, Shen C et al. argued that symptomatic patients with a tumor size lager than 7 cm should be candidates of surgery, and asymptomatic patients with smaller tumors should be followed up closely [26]. In intraosseous and presacral EAMs, surgery is indicated, especially for patients with clinical symptoms, and the masses greater than 7 cm [12,28,29]. It is generally suggested that surgical intervention may be necessary if the mass is larger than 4 cm in diameter [3,21]. In our report, all patients underwent surgeries, because most patients had clinical symptoms and malignancy of the tumor could not excluded by imaging examinations. The treatment strategies for *Case 3 and 6* were discussed in depth and surgery was eventually decided on with the consideration of the potential progression and unpredicted prognosis of the tumor. Postoperative follow-up observation demonstrated excellent prognoses in all our patients as represented by an overall improvement in the quality of life of the patients, and no recurrence and metastasis occurred during the follow-up period. Therefore, we recommend that surgical resection should be the choice of treatment for EAMs with large size, clinical symptoms, imaging diagnoses suspected as malignant tumors, and involvement in the spine and thorax.

5. Conclusions

EAMs are rare benign tumors with good prognosis but limited cases have been reported so far, especially those involving the spinal and intraosseous regions. Conventional imaging differential diagnosis of EAMs remains a big clinical challenge. Our study has demonstrated that the total surgical resection can serve as a radical method for spinal and intraosseous EAMs. For those with no clinical symptoms and small tumor size, dynamic observation is suggested. At present, no study has indicated that the tumor has the tendency of postoperative recurrence, malignant transformation and metastasis. More multi-institutional and larger-sample studies are required to gain more insights into etiologies and clinical characteristics of spinal and intraosseous EAMs.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] R. Spanta, H.A. Saleh, G. Khatib, Fine needle aspiration diagnosis of extraadrenal myelolipoma presenting as a pleural mass, A case report, Acta Cytol 43 (2) (1999) 295–298.
[2] T. Sakai, H. Aiba, M. Nakagawa, H. Hattori, H. Murakami, H. Kimura, Myelolipoma mimicking osteosarcoma in the distal femur, Int J Surg Case Rep 83 (2021), 105997.
[3] H. Rezaee, A. Tavallaii, E. Keykhosravi, M.A. Abouei Mehrizi, Z. Safdari, M. Pishjoo, B. Aminzadeh, A. Alenabi, Spinal myelolipoma – An extremely rare pathology within the lumbar spine: a case report and literature review, Br J Neurosurg (2021) 1–4.
[4] C.A. Olsson, R.J. Krane, R.C. Klugo, S.M. Selikowitz, Adrenal myelolipoma, Surgery 73 (5) (1973) 665–670.
[5] C. Shen, K. Zhou, Y. Lai, J. Fan, L. Liu, G. Che, Review of primary extra-adrenal myelolipoma of the thorax, J Surg Res 207 (2017) 131–137.
[6] Y. Gong, X. Sun, Fine-needle aspiration of a presacral myelolipoma, Diagn Cytopathol 34 (1) (2006) 29–30.
[7] A.K. Singla, G. Kechejian, M.J. Lopez, Giant presacral myelolipoma, Am Surg 69 (4) (2003) 334–338.
[8] Andriandi, A.H.G. Cleven, D.F. Hanff, H. Hartgrink, P.D.S. Dijkstra, Dijkstra, Presacral myelolipoma, case report and literature review, Ann Med Surg (Lond) 57 (2020) 274–280.
[9] L. Chiarini, C. Bertoldi, M. Criscuolo, G. Ferronato, Myelolipomatosis, A report of a case located in the mandible, Minerva Stomatol 41 (4) (1992) 165–172.
[10] J. Wen, H. Chen, W. Yi, X. Zhou, Primary costal myelolipoma: a case report and review of the literature, Int J Clin Exp Pathol 8 (2) (2015) 2202–2204.
[11] M. Sundaram, T. Bauer, A. von Hochstetter, H. Ilaslan, M. Joyce, Intraosseous myelolipoma, Skeletal Radiol 36 (12) (2007) 1181–1184.
[12] N. Papapietro, N. Martinelli, M. Ippolito, C. Amato, V. Denaro, Intraosseous myelolipoma within proximal femoral metaphysis in a patient with previous prostate cancer: a case report, Hip Int 19 (3) (2009) 283–286.
[13] D.G. Omdal, D.E. Baird, B.S. Burton, W.W. Goodhue Jr., E.M. Giddens, Myelolipoma of the thoracic spine, AJNR Am J Neuroradiol 18 (5) (1997) 977–979.
[14] S. Sethi, S. Thakur, S. Jacques, H.D. Aoun, P. Tranchida, Myelolipoma of the Pelvis: A Case Report and Review of Literature, Front Oncol 8 (2018) 251.
[15] V.T. De Montpreville, E.M. Dulmet, A.R. Chapelier, P.G. Dartevelle, J.M. Verley, Extramedullary hematopoietic tumors of the posterior mediastinum related to asymptomatic refractory anemia, Chest 104 (5) (1993) 1623–1624.
[16] T. Ema, R. Kawano, Myelolipoma of the posterior mediastinum: report of a case, Gen Thorac Cardiovasc Surg 62 (4) (2014) 241–243.
[17] K.C. Chang, P.I. Chen, Z.H. Huang, Y.M. Lin, P.L. Kuo, Adrenal myelolipoma with translocation (3;21)(q25;p11), Cancer Genet Cytogenet 134 (1) (2002) 77–80.
[18] P. Fonda, E. de Santiago, M. Guijarro, C. Gamallo. Mediastinal myelolipoma with leucocytosis. BMJ Case Rep. 2013. (2013).
[19] P.J. Kenney, B.J. Wagner, P. Rao, C.S. Heffess, Myelolipoma: CT and pathologic features, Radiology 208 (1) (1998) 87–95.
[20] S. Kawanami, H. Watanabe, T. Aoki, H. Nakata, T. Hayashi, M. Kido, J. Tsukada, S. Eto, Mediastinal myelolipoma: CT and MRI appearances, Eur Radiol 10 (4) (2000) 691–693.
[21] D.A. Qin, X.Q. Ren, S. Zheng, H. Bi. An unusual diagnosis of paravertebral lesions: mediastinal myelolipoma. J Int Med Res. 48(7). (2020). 300060520936972.
[22] L.A. Littrell, J.M. Carter, S.M. Broski, D.E. Wenger, Extra-adrenal myelolipoma and extramedullary hematopoiesis: Imaging features of two similar benign fat-containing presacral masses that may mimic liposarcoma, Eur J Radiol 93 (2017) 185–194.
[23] A. Hakim, C. Rozeik, Adrenal and extra-adrenal myelolipomas – A comparative case report, J Radiol Case Rep 8 (1) (2014) 1–12.
[24] D.Q. Wadood, D.S.A. Qureshi, D.P. Singh, D.J. Freedman, A rare case of co-existing adrenal and pelvic myelolipomas, Radiol Case Rep 13 (5) (2018) 999–1002.
[25] D. Zieker, I. Konigsrainer, S. Miller, U. Vogel, K. Sotlar, W. Steurer, A. Konigsrainer, T.G. Lehmann, Simultaneous adrenal and extra-adrenal myelolipoma – An uncommon incident: case report and review of the literature, World J Surg Oncol 6 (2008) 72.

[26] C. Shen, Z. Han, G. Che, A bilateral neoplasm in chest: a case report and literature review, BMC Surg 14 (2014) 42.
[27] T. Hosaka, Y. Hata, T. Makino, H. Otsuka, S. Koezuka, T. Azumi, K. Ejima, N. Tochigi, K. Shibuya, A. Iyoda, Mediastinal myelolipoma showing gradual enlargement over 9 years: a case report, J Cardiothorac Surg 11 (1) (2016) 91.
[28] V.G. Shenoy, A. Thota, R. Shankar, M.G. Desai, Adrenal myelolipoma: Controversies in its management, Indian J Urol 31 (2) (2015) 94–101.
[29] G. Rizzo, C. Coramusi, G. Pietricola, F. Sionne, F. Castri, D.P. Pafundi, R. Aversa, C. Coco, Laparoscopic approach for a presacral myelolipoma resembling a liposarcoma, J Surg Case Rep 2018 (7) (2018) rjy156.