Interdisciplinary Neurosurgery 21 (2020) 100746

Contents lists available at ScienceDirect

Interdisciplinary Neurosurgery

journal homepage: www.elsevier.com/locate/inat

Case Reports & Case Series

Primary intra and extradural solitary fibrous tumor/hemangiopericytoma of thoracic spine with paravertebral intrathoracic spread: Case report and review of the literature

Vito Fiorenza[a,*], Francesco Ascanio[a], Francesca Ferlito[b], Benedetto Lo Duca[a], Damiano Librizzi[c]

[a] Neurosurgery Department, A.R.N.A.S. "Civico - Di Cristina - Benfratelli" Hospital, Palermo, Italy
[b] Department of Surgical Oncological and Oral Sciences (DICHIRONS), University of Palermo, Palermo, Italy
[c] Thoracic Surgery Department, A.R.N.A.S. "Civico - Di Cristina - Benfratelli" Hospital, Palermo, Italy

ARTICLE INFO

Keywords:
Dumbbell Tumors
Primary Spine Tumors
Solitary Fibrous Tumor/Hemangiopericytoma

ABSTRACT

Solitary fibrous tumors/hemangiopericytomas (SFTs/HPCs), constitute 1% of all CNS tumors. Spinal SFTs/HPCs are extremely rare. To date, few retrospective studies and case reports of primary spinal SFTs/HPCs have been published in the literature. We report clinical and radiological presentation, surgical treatment, and post-operative outcome at three years follow-up of a rare case of primary spinal intra and extradural SFT/HPC of thoracic spine with dumbbell shaped paravertebral intrathoracic spread and multidirectional erosion of the bone. A 73-year-old female presented with progressive lower limbs weakness and hypoesthesia below the rib cage. MRI showed an irregular isointense T5-T7 dumbbell shaped tumor. Tumor resection was successfully carried out through posterior and antero-lateral approach. Histological examination showed a grade II SFT/HPC. No local recurrence nor systemic metastases were observed at three years follow-up. A literature review has been performed to describe epidemiology, radiographic features, treatment, recurrence rate and mean disease-free survival of primary spinal SFTs/HPCs. No radiographic pathognomonic findings have been reported for these tumors. Differential diagnosis must be made with meningioma, schwannoma, chordoma, aggressive hemangioma, metastases, angiosarcoma. Surgical resection is the first choice of treatment, and total resection should be attempted whenever possible in all cases. Postsurgical radiotherapy does not change significantly recurrence rate after GTR, nonetheless it increases mean disease-free survival, especially in patients with extradural SFTs/HPCs. After subtotal resection, adjuvant radiotherapy is necessary to reduce progression of disease. The efficacy of chemotherapy has yet to be determined. Pathological degree and total surgical resection are the most important predictive factors of recurrence.

1. Introduction

The designation hemangiopericytoma was formulated by the pathologists Stout AP and Murray MR [1] in 1942 to name a soft tissue tumor apparently originating from pericytes (pericapillary cells or pericytes of Zimmerman), with a monomorphic population of compact polygonal or fusiform cells and a branching stromal vascular pattern (dilated slit-like "staghorn" blood vessels surrounded by network of reticulin fibers).

First described by Klemperer and Rabin in 1931, as localized forms of primary neoplasms of the pleura, solitary fibrous tumors represent a spectrum of mesenchymal tumors located throughout the body in soft tissue and bone [2].

The 2016 WHO classification of CNS tumors (4th edition) [3] created the merged term "solitary fibrous tumor/hemangiopericytoma" (SFT/HPC) to define such neoplasms.

SFTs/HPCs commonly occur in the thigh, retroperitoneum, trunk, head and neck. Mean age of diagnosis for these lesions is 40–50 years with a slightly male sex prevalence (male-to-female ratio = 1.33:1) [4].

In the central nervous system, they constitute less than 1% of all SFTs/HPCs, approximately 2–4% of all primary meningeal tumors and 1% of all CNS tumors [5,6].

Spinal SFTs/HPCs are extremely rare. SFTs/HPCs may occur in the spinal canal primarily or as metastases from intracranial tumors [7,8]. Spinal SFTs/HPCs may be localized in the vertebral body (causing lytic destruction of bone, no hyperostosis) or be more commonly adherent to the meninges.

To date, about 185 cases of primary spinal SFTs/HPCs have been

* Corresponding author at: Division of Neurosurgery, A.R.N.A.S. "Civico - Di Cristina – Benfratelli" Hospital, Piazza Nicola Leotta 4, 90127 Palermo, Italy.
E-mail address: vito.fiorenza1@gmail.com (V. Fiorenza).

https://doi.org/10.1016/j.inat.2020.100746
Received 5 October 2019; Received in revised form 14 March 2020; Accepted 12 April 2020

published by some retrospective studies and case reports.

In this study, we report an extremely rare case (currently, only 7 cases have been described previously in literature) of primary intra and extradural SFT/HPC of thoracic spine with paravertebral intrathoracic spread (dumbbell tumor type III HPCs according to Liu classification) [9] and multidirectional erosion of the bone (dumbbell tumor type VI, IF stage 2 according to Asazuma classification) [10]. We will discuss our case with a review of the literature to describe epidemiology, radiographic features, treatment, recurrence rate and mean disease-free survival of primary spinal SFTs/HPCs.

2. Methods

We describe clinical and radiological presentation, surgical treatment, and post-operative outcome at three years follow-up of a rare case of primary intra and extradural dumbbell shaped SFT/HPC of thoracic spine. A literature review using the key words, “spinal solitary fibrous tumor/hemangiopericytoma”, “spinal SFT/HPC”, “primary osseous hemangiopericytoma of the spine” “spinal hemangiopericytomas”, “primary solitary fibrous tumor of the spine”, “spinal solitary fibrous tumor”, was performed using an online database search (PubMed, Scopus, ScienceDirect, Cochrane database) and relevant case series and case reports were identified. WHO grade was not included in the analysis due to obvious discrepancies between past and current WHO grading system (most studies were conducted when HPC and SFT were treated as separate entities). To assess statistical significance, chi-square test of association was used. Tests with two-tailed p values < 0.05 were considered statistically significant.

3. Case report

A 73-year-old female presented with progressive lower limbs weakness and hypoesthesia, with tingling and numbness below the seventh thoracic rib over a period of 3 months. On admission, the neurological examination showed spastic paraparesis with segmental weakness of grade 4-/5 Medical Research Council (MRC), and superficial sensory loss below T7 dermatome without involvement of proprioceptive sensitivity. The Babinski sign and pathologic tendon reflexes were present in both lower limbs. There were no sphincter disorders.

Magnetic resonance imaging (MRI) of the spine and computed tomography scan (CT) of the chest showed at T5-T7 an irregular isointense soft tissue mass with diffuse multiple spots of low signal intensity on T1-weighted images, and high signal intensity on T2-weighted images, located posterolaterally to the thecal sac, and destroying the right posterior elements of T5 and T6 vertebrae (laminae, facet joints). On the right side, the tumor occupied the epidural space, and caused erosion of the transverse process, of the posterior arch of the right 5th rib, the pedicle and posterior body of T5 vertebra, extending as a well-circumscribed voluminous mass through the T5-T6 and T6-T7 neural foramens into paravertebral intrathoracic area (dumbbell shaped tumor). Gadolinium-enhanced MRI showed a heterogeneous enhancement with likely intradural component (Fig. 1).

On the basis of the morphological data, en-bloc resection was not feasible. The tumor was removed by gross total resection via two surgical stages: the first stage by a posterior approach, and a second stage by an antero-lateral approach. The posterior approach consisted in gross total resection of T5-T6 posterior arches. No extraosseous soft tissue extension of tumor was detected. The tumor was mainly localized in extradural space. No neoplastic dural erosion nor invasion was observed. Intradural spread of tumor occurred through right T5 and T6 nerve roots, mimicking schwannomas (Fig. 2).

Postero-lateral extradural portion of the tumor was sectioned and removed. Involved T5 and T6 right nerve roots were identified and cut. Next, the dura mater was opened with a linear longitudinal incision to provide satisfactory visualization and subsequent removal of the intradural extension of the tumor mass. A further transverse incision was made along the course of the involved nerve roots to remove the intraneural portion of tumor.

Neoplastic bone involvement of the right transverse process, pedicle and posterior body of T5 vertebra was detected. The posterior cortex of the vertebral body and pedicle was displaced and eroded but not destroyed. In summary, the first posterior surgical step included gross total resection of T5-T6 posterior arches, right pedicle and posterior body of T5 vertebra, intra and extradural tumor, section of the nerve roots involved by the tumor thereby achieving the release of the dura from the paravertebral tumor portion.

The antero-lateral surgical stage was then performed via antero-lateral transthoracic transpleural approach. This surgical step included en-bloc resection of paravertebral intrathoracic mass; no pleural involvement was present; bone involvement was present at the posterior arch of the right 5th rib.

After surgery, significant immediate neurological improvement was observed. Post-operative MRI revealed complete tumor resection (Fig. 3).

Histological examination showed a grade II SFT/HPC (Fig. 4.). The patient underwent radiotherapy of the thoracic area (total dose of 46 Gy). No local recurrence nor systemic metastases were observed at three Years follow-up (Fig. 5).

4. Result

Our statistical analysis of clinical cases reported in the literature showed that 32% of SFTs/HPCs were located in cervical spine, 1.6% in cervicothoracic, 43.5% in thoracic, 3.2% in thoracolumbar, 17.2% in lumbar, an 2% in sacral spine (Table 1).

Twenty-three (12.4%) were vertebral, 73 (39.4%) extradural, 57 (30.8%) intradural extramedullary, 22 (11.8%) intradural intramedullary, 11 (5.9%) intra-extradural, 8 (4.3%) of them with paravertebral spread.

Thirty-nine patients were not included in our statistical analysis due to the lack of recurrence-related data. The overall recurrence rate was 37.5% (55/147 patients) with a mean recurrence-free survival of 5.2 years (standard deviation [SD] 3.9; range 0.7–25), regardless of the treatment modality. The recurrence rate was significantly lower in patients who underwent total resection (TES and GTR ± RT) (28%, $p < 0.01$) compared to subtotal resection (STR ± RT) (69,7%, $p < 0.01$). With regard to the treatment modality, no statistical differences in recurrence rate and mean disease-free survival were observed in cases of GTR (25.3%) vs GTR + RT (34%) ($P > 0.05$, $P = 0.447$).

Progression of disease was observed in all patients who underwent to STR. Statistically significant difference in recurrence rate (progression of disease) was detected in patients who underwent STR (100%) when compared with those undergoing subtotal resection plus RT (56.5%) ($P < 0.05$, $P = 0.0170$). However, even in these patients, adjuvant radiotherapy did not increase mean disease-free survival ($P > 0.05$; $P = 0,0614$); mean recurrence-free survival was 2.1 years after STR (SD 1.2; range 0.7–5) vs 7.3 years after STR + RT (SD 7.6; range 1.33–25).

No recurrence was observed in all cases of intradural intramedullary SFTs/HPCs who underwent GTR. Overall recurrence rate in these patients was 18% (all patient underwent to STR).

In cases of intradural extramedullary tumors the recurrence rate was 44%. In these patients, statistically significant difference was observed in recurrence rate if patient underwent GTR ± RT (38,7%) compared to STR ± RT (85.7%) ($P < 0.05$; $P = 0.0194$). Post GTR radiotherapy does not reduce recurrence rate ($P > 0.05$, $P = 0.7906$) and does not change significantly mean disease-free survival (5.2 years after GTR [SD 4.9, range 1.83–18] vs 4.7 years after GTR + RT [SD 0.92, range 4–6]; P 0.6923).

Recurrence rate was 38,4% in patients with extradural SFTs/HPCs.

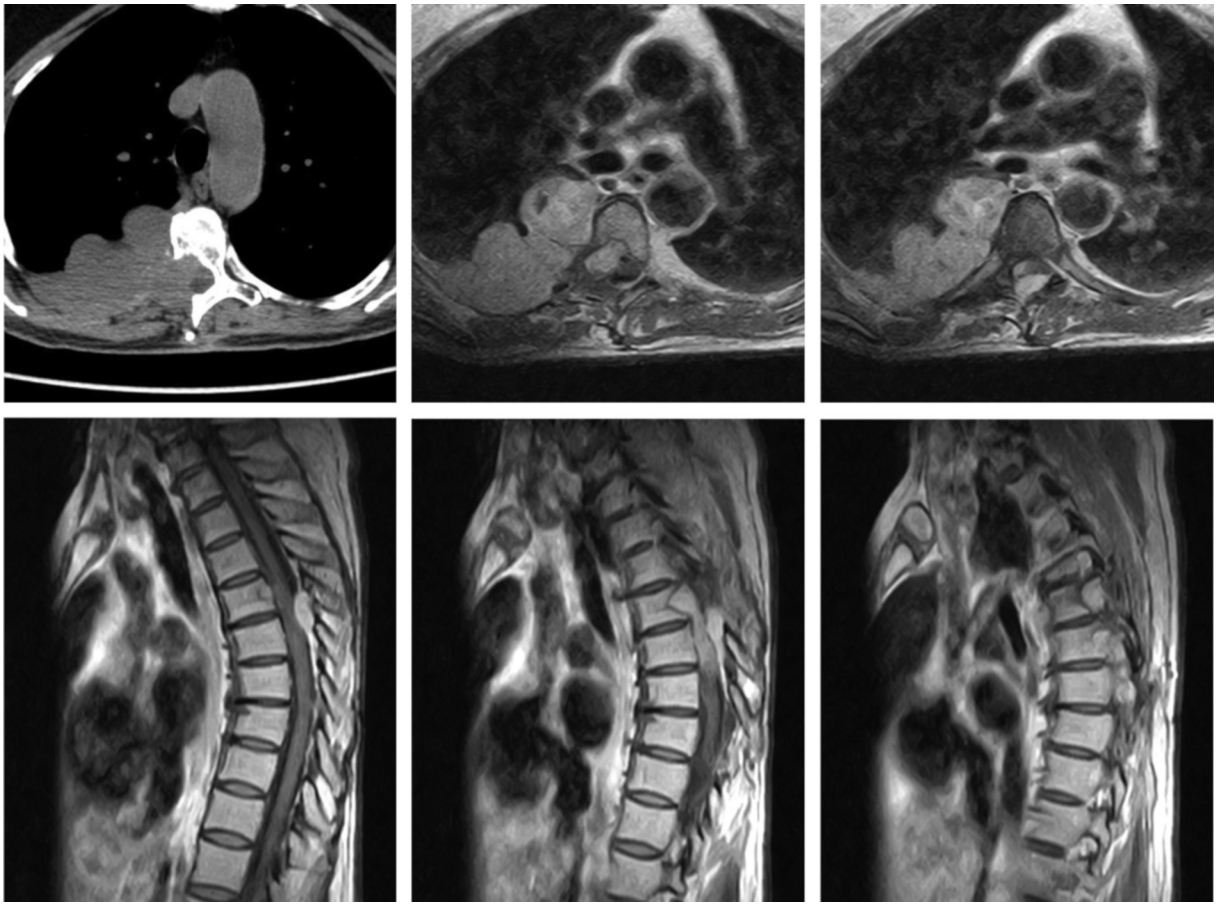

Fig. 1. Pre-operative MRI and CT scan.

No statistical difference in recurrence rate was observed in cases who underwent GTR ± RT (34.3%) vs STR ± RT (57%) ($P > 0.05$; $P = 0.2620$). In these patients, post GTR radiotherapy did not reduce recurrence ($P > 0.05$, $P = 0.2159$), but increased mean disease-free survival (1.5 years after GTR [SD 0.98, range 1–3] vs 6 years after GTR + RT [SD 2.02, range 4.5–10]; P 0.0033).

Insufficient data are available about the benefit of adjuvant radiotherapy concerning recurrence rate and mean disease-free survival after

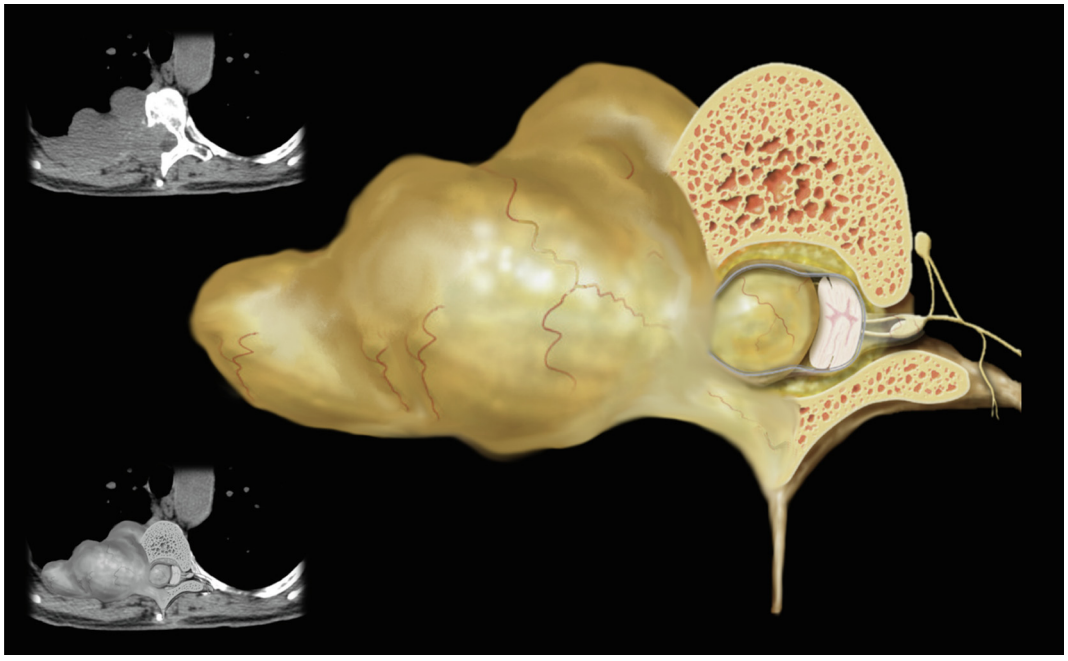

Fig. 2. Schematic picture of intra/extradural and paravertebral dumbbell shaped SFT/HPC.

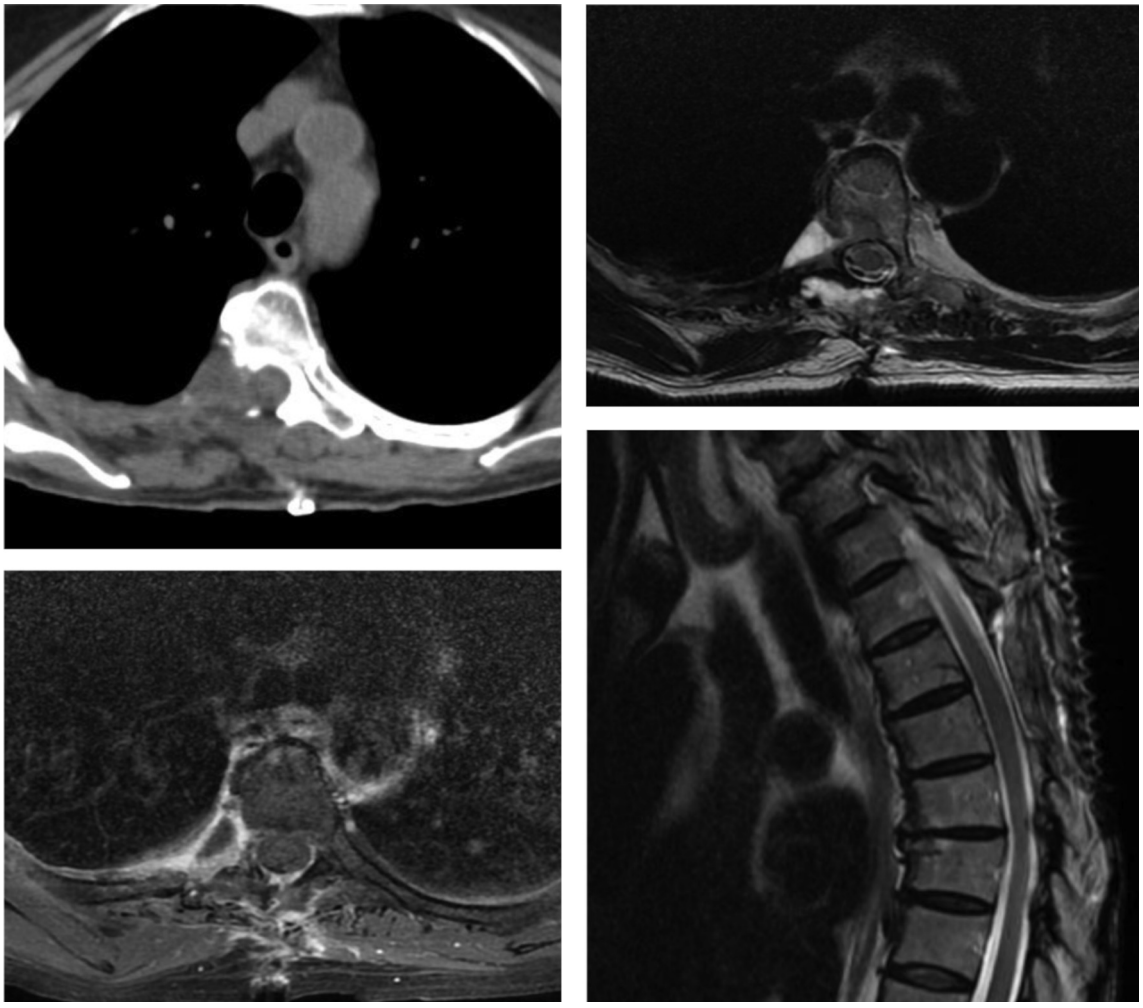

Fig. 3. Early post-operative MRI and CT scan.

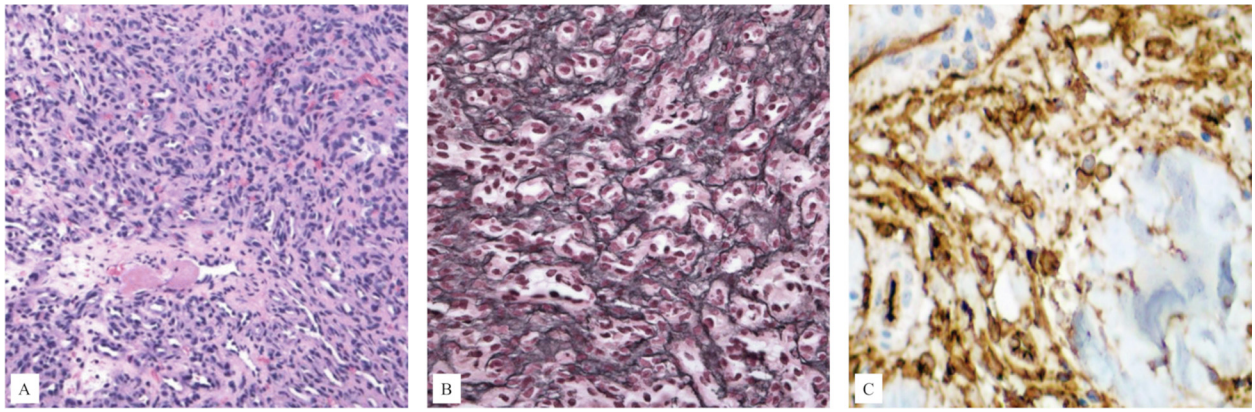

Fig. 4. Histopathological appearance: A. Haematoxylin and eosin (H&E) stain. B. Positive Vimentine stain. C. Positive CD34 stain.

STR both for intradural extramedullary and extradural SFTs/HPCs (the sample size is too small to allow a reliable calculation both of the t statistic and chi-square tests).

Recurrence rate was 43.4% in patients with vertebral SFTs/HPCs, with significantly better prognosis in recurrence rate (P = 0,0251) in cases of total resection, especially TES, in comparison with those of subtotal resection. Mean recurrence-free survival in patients undergoing total resection (TES + GTR ± RT) was 3,84 (SD 1.97; range 1.91–6.08) years. Conversely, patients with a subtotal resection had a mean recurrence-free survival time of 2 (SD 1.59; range 1–4.41) years. Insufficient data are available about the benefit of adjuvant radiotherapy.

Recurrence rate of 50% was observed in patients with intra/extradural and paravertebral SFTs/HPCs who underwent GTR with a mean of recurrence-free survival of 11 years (SD 2; range 9–12.8). Conversely, all patients with a subtotal resection had a progression of disease at 10 years (SD 8.37; range 4–22) of median of follow-up. Insufficient data are available about the benefit of adjuvant radiotherapy.

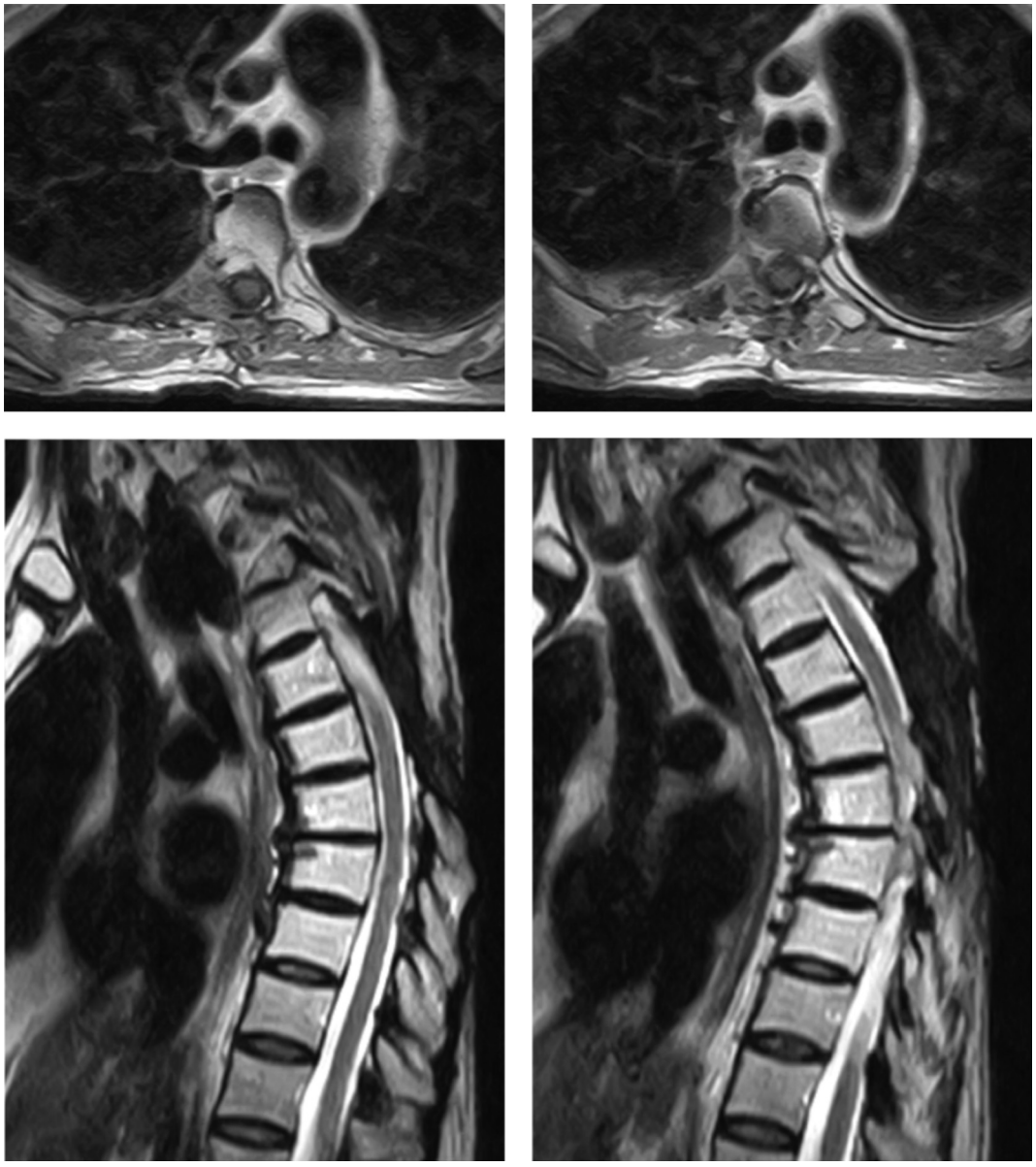

Fig. 5. Postoperative follow-up MRI at 3 years.

5. Discussion

For about ten years, soft tissue pathologists have classified hemangiopericytoma as neoplasm in the spectrum of solitary fibrous tumors (an ubiquitous mesenchymal neoplasm of probable fibroblastic type). Conversely, neuropathologists have maintained the term hemangiopericytoma, since the clinical and pathologic manifestations of solitary fibrous tumors and hemangiopericytomas are quite different. Indeed, in the central nervous system, HPCs are locally aggressive, malignant neoplasms with a high rate of local recurrence, propensity to leptomeningeal spread and distant extraneural delayed metastases. The most common sites for metastases are the lungs and bone [11]. The probability of local recurrence is about 65% and 90% respectively at 5 and 12 years. The probability of extraneural metastases is about 80% at 12 years [12]. On the other hand, most peripheral soft tissue tumors have a benign clinicopathologic course and are treated by gross total resection.

The 2016 WHO classification of CNS tumors (4th edition) [3] created the merged term solitary fibrous tumor/hemangiopericytoma to define such neoplasms, both because hemangiopericytomas present histological features similar to the “cellular” variant of solitary fibrous tumor [13], and because they share the same molecular genetic profile with solitary fibrous tumors: NAB2 and STAT6 genes fusion, generated by genomic inversion of 12q13 locus, which leads to STAT6 nuclear expression able to be detected by immunohistochemistry techniques [14,15]. As a result, systemically the term hemangiopericytoma is no longer routinely used. The meningeal hemangiopericytoma and solitary fibrous tumor of the dura are considered as one entity [3].

WHO CNS classification has assigned three grades of malignancy scale to the new entity of SFT/HPC: grade I corresponds to fibrous variant of solitary fibrous tumor (highly collagenous, relatively low cellularity, spindle cell lesion); grade II corresponds to the cellular variant (less collagenous, round/ovoid cells and “staghorn” vasculature) that have been previously diagnosed as meningeal hemangiopericytoma; grade III shows ≥ 5 mitoses per 10 high-power fields (it corresponds to anaplastic hemangiopericytoma according to the previous classification) [3].

The neoplasm appears grossly a solid, well-demarcated mass, and it tends to bleed during removal.

No radiographic pathognomonic findings have been reported for

Table 1
Review of the clinical features of personal and literature cases.

Article	Cases	Level	Location	Treatment	Recurrence	Follow-up; Recurrence-Free Survival (y)
Schirger (1958) [27]	1	T2	Extradural	GTR	YES	1
Kruse (1961) [28]	1	C3	Intradural extramedullary	GTR + RT	YES	4
Pitlyk (1965) [29]	3	C3	Intradural extramedullary	GTR	YES	18
		C4	Intradural extramedullary	GTR	YES	2
		T8	Intradural extramedullary	GTR	NO	10
Kriss (1968) [30]	1	C6-7	Extradural	GTR + RT	NO	0.75
Fathie (1970) [31]	1	T6	Extradural	GTR	N/K	N/K
Gerner (1974) [32]	1	L5	Extradural	GTR + RT	N/K	N/K
McMaster (1975) [33]	5	T1-2	Extradural	N/K	N/K	N/K
		T6-7	Extradural	N/K	N/K	N/K
		T10	Extradural	N/K	N/K	N/K
		T11	Extradural	N/K	N/K	N/K
		S1	Extradural	N/K	N/K	N/K
Harris (1978) [34]	2	C2-6	Extradural	STR + RT	NO	5
		L2	Extradural	STR + RT	NO	4
Stern (1980) [35]	1	C6	Extradural	GTR	NO	1
Cappabianca (1981) [36]	2	C5	Extradural	GTR	NO	2
		C6	Extradural	STR + RT	NO	0.1
Muraszko (1982) [37]	4	T11	Extradural	GTR + RT	YES	6
		T12	Extradural	GTR + RT	N/K	N/K
		T12-L2	Extradural	GTR + RT	N/K	N/K
		L3-4	Intra/extradural	GTR	YES	12
Ciappetta (1985) [38]	2	C4	Intradural extramedullary	GTR	YES	7
		C6	Extradural	STR + RT	NO	2
Bridges (1988) [39]	1	S1	Extradural	GTR + RT	NO	0.75
Salvati (1991) [40]	1	L1-3	Extradural	GTR + RT	NO	10
Carneiro (1996) [41]	1	L1	Intradural intramedullary	STR	YES	5
Alston (1997) [42]	1	T4-5	Intradural intramedullary	GTR	N/K	N/K
Malek (1997) [43]	1	T7-8	Intradural extramedullary	GTR	N/K	N/K
Brumori (1999) [44]	1	T12-L1	Extradural	GTR	NO	0.3
Kanahara (1999) [45]	1	C6-7	Intradural extramedullary	GTR	N/K	N/K
Kataoka (1999) [46]	1	C4-5	Intra/extradural/paravertebral (dumbbell)	GTR	N/K	N/K
Vorster (2000) [47]	1	T2-3	Intradural extramedullary	GTR	NO	0.58
Mordani (2000) [48]	1	C5	Intradural intramedullary	GTR	NO	1.5
Ackerman (2001) [49]	1	T10	Intradural extramedullary	GTR	N/K	N/K
Kurtkaya (2001) [50]	1	T3	Intradural extramedullary	GTR	NO	1
Akhaddar (2002) [51]	1	T4-6	Extradural	GTR + RT	NO	3
Betchen (2002) [52]	1	L4	Intradural extramedullary	GTR	NO	0.5
Ijiri (2002) [53]	1	L1-2	Extradural	GTR	NO	2
Endo (2003) [54]	1	C2-4	Extradural (dumbbell)	GTR	N/K	N/K
Bohinski (2004) [55]	1	C4	Intradural intramedullary	GTR	NO	0.83
Pizzolitto (2004) [56]	2	T7-8	Intradural extramedullary	GTR	NO	1.5
		C3-5	Intradural intramedullary	GTR	NO	1
Piana (2004) [57]	1	L1-2	Extradural	GTR	N/K	N/K
Mohammadianpanah (2004) [26]	1	T2	Extradural	STR + RT + CT	N/K	N/K
Jallo (2005) [58]	4	C6-7	Intradural intramedullary	GTR	NO	3.5
		T5-6	Intradural intramedullary	GTR	NO	1.6
		T2-3	Intradural extramedullary	GTR	NO	5
		T5	Intradural extramedullary	GTR	NO	4.8
Kashiwazaki (2007) [59]	1	T4-6	Intradural extramedullary	GTR	NO	3
Kumar (2007) [60]	1	T4-5	Extradural	STR + RT	NO	0.75
Zhao (2007) [61]	23	10 Cervical	Intradural extramedullary	GTR	YES	Mean 4.7
		9 Thoracic	Intradural extramedullary	GTR	NO	
		3 Lumbar	Intradural extramedullary	GTR	NO	
		1 Sacral	Intradural extramedullary	GTR + RT	YES	
			19 Extradural (73% recurrence)	3 GTR	N/K	
				2 GTR + RT	N/K	
				10 STR	N/K	
				4 STR + RT	N/K	
Chou (2009) [62]	1	T10	Intradural extramedullary	GTR	NO	3
Fitzpatrick (2009) [4]	1	L4-5	Intradural extramedullary	GTR + RT	NO	N/K
Kakimaru (2009) [63]	1	T8-10	Extradural paravertebral	GTR	NO	3
Ciappetta (2010) [64]	1	T6-7	Intradural intramedullary	GTR	NO	2
Ishii (2009) [65]	1	C5	Intradural intramedullary	GTR	NO	0.83
Fargen (2011) [66]	1	C2-3	Intradural intramedullary	GTR	NO	2
Moscovici (2011) [67]	1	T9-10	Intradural extramedullary	GTR	NO	2
Ackerman (2011) [49]	1	T10	Intradural extramedullary	GTR	NO	N/K
Santillan (2011) [68]	1	C2	Extradural	GTR + RT	N/K	0.25
Brigui (2012) [69]	2	T6-7	Intradural extramedullary	GTR	NO	2.41
		T7-8	Extradural paravertebral	GTR	YES	1
Mariniello (2012) [70]	2	C4-7	Intradural extramedullary	GTR	NO	1
		T6-7	Intradural intramedullary	GTR	NO	1
Torigoe (2012) [71]	1	T6-7	Intradural extramedullary	GTR	YES	5

(*continued on next page*)

Table 1 (*continued*)

Article	Cases	Level	Location	Treatment	Recurrence	Follow-up; Recurrence-Free Survival (y)
Nakashima (2013) [72]	1	C3-4	Intra/extradural	GTR	YES	9
Shirzadi (2013) [25]	3	C0-C3	Intradural extramedullary	GTR	YES	3
		C0-C4	Intradural extramedullary	GTR	NO	3
		T9-10	Intradural extramedullary	GTR + RT	NO	3
Drazin (2013) [73]	1	C0-C4	Intradural extramedullary	GTR + RT	NO	5
Lee (2013) [74]	1	C1-2	Intradural extramedullary	GTR	NO	2
Liu (2013) [9]	26	L3-4	Intradural extramedullary	GTR + RT	NO	2.8
		C2-7	Extradural	STR + RT	YES	1.6
		L3-S2	Intradural extramedullary	GTR + RT	NO	3
		C2-3	Intradural extramedullary	GTR + CT	YES	6
		T3-5	Intra/extradural/paravertebral	GTR + RT	YES	12.8
		T11-L2	Extradural	GTR + RT	YES	5.4
		L1-5	Intradural extramedullary	STR	YES	0.7
		C2-4	Intra/extradural/paravertebral	STR + RT	YES	10.8
		T5-6	Intradural intramedullary	GTR + RT	NO	6.7
		L2	Intra/extradural/paravertebral	STR + RT	YES	4
		C5-7	Intradural intramedullary	GTR + RT	NO	1.8
		C2-3	Extradural	GTR + RT	YES	4.6
		C5-6	Extradural	GTR + RT	YES	6
		C1-4	Extradural	STR + RT	NO	2.1
		T9-10	Intra/extradural/paravertebral	STR + RT	YES	22
		L1-2	Intradural extramedullary	STR + RT	YES	12.8
		L5-S1	Intra/extradural/paravertebral	STR + RT	YES	4.5
		T12-L1	Extradural	STR + RT	YES	2.8
		T5-6	Extradural	GTR + RT	NO	2.5
		C2-3	Intradural extramedullary	STR + RT	YES	4.8
		T5-7	Intradural extramedullary	STR + RT + CT	YES	25
		C7-T1	Extradural	GTR + RT	YES	4.5
		L1-2	Extradural	STR + RT	YES	2
		C1-2	Extradural	GTR + RT	YES	10
		T11-12	Intra/extradural/paravertebral	GTR + RT	NO	5.5
		T12-L1	Intradural extramedullary	GTR + RT	YES	6
Zhang (2014) [75]	1	C6-T2	Extradural	GTR	NO	1
Raghvendra (2014) [76]	1	C3	Extradural	GTR + RT	NO	1
Jayashankar (2014) [77]	1	T5-6	Extradural	GTR	YES	N/K
Kaur (2014) [78]	1	T9	Intradural extramedullary	GTR + RT	NO	5
Robert (2014) [79]	1	T9-10	Intradural intramedullary	GTR	NO	0.5
Bruder (2015) [55]	1	T8-9	Intradural intramedullary	GTR	N/K	N/K
Lavrador (2015) [80]	1	T11-12	Extradural paravertebral (dumbbell)	GTR	NO	0.5
Türk (2015) [81]	2	C1-2	Intradural extramedullary	GTR	NO	N/K
		T9-10	Intradural extramedullary	GTR	NO	N/K
Das (2015) [82]	5	C4-5	Intradural extramedullary	GTR + RT + CT	NO	2
		T7-9	Intra/extradural	GTR	NO	1
		T8-10	Intradural intramedullary	STR + RT + CT	NO	2
		T11-L1	Intradural extramedullary	GTR + RT	NO	0.75
		C5-6	Extradural	STR + RT + CT	YES	5
Chew (2017) [83]	1	T9	Intradural extramedullary	GTR	NO	1
Li (2017) [17]	1	T6-7	Extradural	GTR	NO	1
Yi (2017) [16]	11	L5	Vertebral (extradural)	GTR	NO	2.8
		L3	Extradural paravertebral	GTR	NO	5.8
		T12	Vertebral (extradural)	GTR	NO	5.75
		C2-3	Extradural (dumbbell)	GTR	NO	5.6
		L5	Extradural	GTR	NO	5.1
		T11	Vertebral (extradural)	GTR	YES	0.8
		L4-5	Extradural (dumbbell)	GTR	NO	4.25
		T11-12	Extradural paravertebral	STR + RT	NO	1.6
		T4-S1	Intradural extramedullary (multiple)	GTR	N/K	N/K
		C2-4	Extradural (dumbbell)	GTR	YES	1.08
		T2-3	Extradural	GTR	NO	3
Wang H (2018) [84]	1	T7-8	Intradural extramedullary	GTR + RT	NO	4
Jia (2018) [18]	20	C7-T1	Vertebral (extradural)	TES + RT	NO	7.75
		T5-6	Vertebral (extradural)	TES	YES	6.08
		T7	Vertebral (extradural)	GTR	YES	5.83
		T2	Vertebral (extraosseous soft tissues)	GTR + RT	YES	2.3
		L3	Vertebral (extraosseous soft tissues)	TES	NO	2.75
		L1	Vertebral (extradural and extraosseous soft tissues)	GTR + RT	YES	1.91
		T7-9	Vertebral (extradural)	STR + RT	YES	4.41
		T8	Vertebral (extraosseous soft tissues)	TES + RT	NO	3.41
		C5-6	Vertebral (extraosseous soft tissues)	GTR + RT	YES	3.08
		C4-5	Vertebral (extradural and extraosseous soft tissues)	GTR + RT	NO	1
		C5-7	Vertebral (extradural)	GTR + RT	NO	0.91

(*continued on next page*)

Table 1 (*continued*)

Article	Cases	Level	Location	Treatment	Recurrence	Follow-up; Recurrence-Free Survival (y)
		C5-6	Vertebral (extradural and extraosseous soft tissues)	STR + RT	NO	0.58
		C2	Vertebral (extraosseous soft tissues)	STR + RT	YES	1.33
		T9	Vertebral (extradural and extraosseous soft tissues)	GTR + RT	NO	2
		T1	Vertebral (extradural and extraosseous soft tissues)	STR + RT	YES	1.41
		S1-3	Vertebral (extradural and extraosseous soft tissues)	GTR + RT	NO	3
		L1-2	Vertebral (extradural)	GTR	NO	2.33
		L5-S2	Vertebral (extradural and extraosseous soft tissues)	GTR + RT	NO	1.66
		T4	Vertebral (extradural and extraosseous soft tissues)	STR	YES	1
		L2	Vertebral (extradural)	TES	NO	2.83
Wang J (2019) [24]	16	T5-6	Intradural intramedullary	STR	YES	2.1
		C5-7	Intradural extramedullary	STR	YES	2.9
		T3-4	Intradural extramedullary	GTR + RT	NO	8
		L2-3	Intradural intramedullary	STR	YES	2.08
		T8	Intradural extramedullary	GTR + RT	YES	4.08
		L1	Intradural intramedullary	GTR + RT	NO	6.83
		C4-6	Intradural extramedullary	STR	YES	2.6
		T9-10	Intradural intramedullary	STR	YES	1.75
		C5-6	Intradural intramedullary	GTR + RT	NO	6.3
		T9	Intradural extramedullary	GTR + RT	NO	5.8
		T3-4	Intradural extramedullary	GTR	NO	5.58
		T6	Intradural extramedullary	GTR	YES	1.83
		L3-5	Intradural intramedullary	STR	YES	1.58
		T11-12	Intradural extramedullary	STR + RT	NO	3.5
		T4	Intradural extramedullary	GTR	NO	2.91
		C6-7	Intradural extramedullary	GTR	NO	2
Zhang (2019) [85]	1	L4	Extradural (dumbbell)	GTR	YES	3
Present case	1	T5-7	Intra/extradural/paravertebral	GTR + RT	NO	3
Total	186	Level	Location	Treatment	Recurrence /Progression	
		60 Cervical	23 Vertebral	3 TES	YES 1, NO 2 –	
		3 Cervicothoracic	73 Extradural	2 TES + RT	–, NO 2 –	
		81 Thoracic	57 Intradural extramedullary	79 GTR	YES 16, NO 50, N/K 13	
		6 Thoracolumbar	22 Intradural intramedullary	47 GTR + RT	YES 14, NO 27, N/K 6	
		32 Lumbar	11 Intra/extradural (8 paravertebral)	1 GTR + RT + CT	–, NO 1, –	
		4 Sacral		1 GTR + CT	YES 1, – –	
				19 STR	YES 9, N/K 10 –	
				25 STR + RT	YES 12, NO, 9, N/K 4	
				4 STR + RT + CT	YES 2, NO 1, N/K 1	
				5 N/K		

CT: chemotherapy, GTR: gross total resection, N/K: not known, RT: radiation treatment, STR: subtotal resection, TES: total en-bloc spondylectomy.

Table 2
Differential diagnosis based on radiographic and pathological features.

Differential diagnosis	Radiographic and pathological features
SFTs/HPCs	Usually isointense with spinal cord and display prominent vascular flow voids on T1 and T2-weighted MRI. Heterogeneous enhancement on T1-weighted gadolinium-enhanced images. Narrow-based dural attachment.
Meningioma	Usually well circumscribed, nonerosive, calcification helpful clue, common in women, thoracic spine. Homogeneous enhancement on T1-weighted gadolinium-enhanced images. Broad based dural attachment.
Schwannoma	Avidly enhancing mass in spinal canal, neural foramen; Hyperintense on T2WI; Bony remodeling, foraminal enlargement, or vertebral scalloping
Chordoma and Other Primary Bone Malignancies	Destructive process centered in bone; Chordoma most commonly seen in sacrum, sinus; Extraosseous/epidural soft tissue mass.
Aggressive Hemangioma	Thickened vertical trabecula with in area of circumscribed osteolysis; avid enhancement; associated epidural or paravertebral soft tissue mass
Hematogenous metastases	Renal cell, thyroid carcinoma. Usually centered in cancellous bone, posterior vertebral body commonly involved; if dural-based, quite focal
Angiosarcoma	Very rarely in spine. More haphazard boundaries

this tumor. It often mimics spinal meningioma or schwannoma but presents more bone erosion and blood supply. Differential diagnosis must be made with meningioma, schwannoma, chordoma and other primary bone malignancies, aggressive hemangioma, metastases, angiosarcoma (Table 2). The presence of serpentine vascular flow voids on T1 and T2 weighted images, a dural tail sign with narrow base attachment, the absence of calcifications, and adjacent bony erosion on preoperative MRI may point to SFT/HPC [16].

Spinal SFTs/HPCs can be divided in to 4 types: vertebral (osseous), paravertebral, spinal canal (extradural, intradural extramedullary, intradural intramedullary), and mixed, according to the location of the maximal diameter of the tumor [16]. Extradural spinal SFTs/HPCs can

be further classified as being based on either dura, nerve or bone [17]. Anatomically, the spinal cord, leptomeninges, dura, nerve roots, or ligaments around the spine may represent the potential site of origin of SFTs/HPCs.

Surgical resection is the first choice of treatment in all cases. Surgical treatment plays a crucial role in the management of spinal (meningeal and osseous) SFTs/HPCs, and total resection should be attempted whenever possible [18,19].

It is important to distinguish SFT/HPC of the spinal meninges from SFT/HPC of the osseous spine. Clinical and pathological manifestations of intraspinal meningeal SFTs/HPCs are different from primary osseous spinal SFTs/HPCs. Vertebral (osseous) SFTs/HPCs must be considered as primary bone tumors of the spine.

Surgical planning of osseous vertebral SFTs/HPCs must be based according to Weinstein-Boriani-Biagini (WBB) surgical staging system [20].

Surgical treatment of spinal osseous (vertebral) SFTs/HPCs (WBB staging A–E), includes total en-bloc spondylectomy (TES), piecemeal total spondylectomy, and subtotal resection. TES should be the first surgical treatment whenever possible [18,21–23]. Other investigators reported that piecemeal total resection with post-operative radiotherapy was sufficient for spinal grade II SFTs/HPCs because of its slow and non-aggressive course [6,22]. Piecemeal total resection showed better prognosis than subtotal resection (subtotal resection led to high rate of tumor recurrence). According to the case series reported by Jia Q. et al. [18], in patients who underwent piecemeal total resection the local recurrence rate was as high as 60% for grade III and 40% for grade II spinal osseous SFTs/HPCs. TES showed local recurrence rate as high as 20% at 6 years of follow-up. No statistical difference in recurrence rate was observed in the cases who underwent adjuvant radiotherapy. However, radiotherapy should be regarded as a beneficial supplement after removal of spinal osseous SFTs/HPCs and, to date, it is recommended to lower the recurrent rate [18]. Chemotherapy was ineffective in the treatment of spinal osseous SFTs/HPCs. WHO grade III is an adverse prognostic factor for both recurrence and survival [18,21,23]. Careful preoperative planning and the choice of the proper surgical procedure, prevent spinal cord injury, spinal instability, vascular hemorrhagic complications and, if appropriate, they further reduce recurrences.

In our opinion, in cases of spinal canal (extradural, intradural extramedullary, intradural intramedullary), and paravertebral (dumbbell) SFTs/HPCs, surgical planning must be based according to Liu [9] and Asazuma [10] classification.

Liu H. et al. [9], divided spinal canal HPCs into 3 types and 5 subtypes: type I, extradural (IA, intracanal type; IB, intra- and extracanal type); type II, intradural (IIA, extramedullary type; IIB, intramedullary invasion type); type III, intra- to extradural and paravertebral type.

Type III HPCs develop an “hourglass” shape and may look like the most common dumbbell spinal schwannomas. Asazuma et al. [10] have developed a classification system based on a three-dimensional morphology for dumbbell tumors according to they are distinguished on the basis of anatomic relationships with surrounding structures. Type I tumors are located only in the spinal canal with intradural and extradural growth patterns. Type II are epidural tumors and include three subtypes: a (foraminal), b (paravertebral), and c (foraminal and paravertebral), distinguished according to the degree of extraforaminal spread. Type III includes intra/extradural tumors with foraminal (IIIa) and paravertebral spread (IIIb). Type IV tumors are extradural and intravertebral, invading only the vertebral body. Type V lesions are extradural with laminar invasion and extralaminar spread. Type VI tumors show multidirectional erosion of the bone. Additional classification indicates the degree of craniocaudal tumor invasion related to the number of intervertebral foramens (i.e. IF 2: tumors involve two intervertebral foramens) (Table 3).

Surgical treatment for spinal meningeal SFTs/HPCs is similar to meningiomas and schwannomas and en-bloc resection or surgical gross total resection (GTR), when feasible, is sufficient in cases of grade I SFTs/HPCs. Gross total resection with postoperative radiotherapy is the recommended treatment for spinal grade II-III SFTs/HPCs. WHO grade III is a predictive factor for recurrence [6,22,24].

Table 3
Comparison between Liu spinal HPCs classification and Asazuma dumbbell tumors classification.

Liu classification		Asazuma classification	
Type I: extradural	Ia: Intracanal Ib: intra/extracanal	Type I: intra/extradural intracanal	
Type II: intradural	IIa: extramedullary IIb: intramedullary	Type II: epidural	IIa: foraminal IIb: paravertebral IIc: foraminal/paravertebral
Type III: intra/extradural and paravertebral		Type III: intra/extradural	IIIa: foraminal IIIb: paravertebral
		Type IV: extradural, intravertebral (only vertebral body)	
		Type V: extradural, extralaminar	
		Type VI: multidirectional erosion of the bone	

Decreased survival has been associated with increased mitoses (5 or more mitotic figures/10 high-power fields), high cellularity, nuclear pleomorphism, hemorrhage, and necrosis (grade III SFT/HPCs). In these cases, surgical removal plus adjuvant radiotherapy is the preferred treatment (local tumor control is obtained more often with radiotherapy than surgery alone), despite there is no consistent benefit of radiotherapy concerning overall survival [9,25]. Radiotherapy and/or chemotherapy are indicated for unresectable tumors. Chemotherapy is also used for the treatment of metastatic disease [24–26]. However, chemotherapy has proved to be of little benefit [24]. Prognosis of grade III SFTs/HPCs is better than for anaplastic meningiomas but it is still unfavorable in the long term.

Our statistical analysis demonstrates that better prognosis was observed in patients with intradural intramedullary SFTs/HPCs who underwent GTR.

Overall, there was no statistically significant increase in disease-free survival among patients undergoing GTR plus adjuvant radiotherapy when compared with those undergoing gross total resection alone. Adjuvant radiotherapy after STR, significantly reduce progression of disease (calculating all cases, regardless of tumor location). Indeed, insufficient data are available about the benefit of adjuvant radiotherapy concerning recurrence rate and mean disease-free survival after STR, both for intradural extramedullary and extradural SFTs/HPCs (the sample size is too small to allow a reliable calculation both of the t statistic and chi-square tests).

Most patients (87%) with intradural extramedullary SFTs/HPCs were treated with GTR. Recurrence rate of 85.7% after STR (± RT), indicates that radical excision should be attempted whenever possible. Adjuvant radiotherapy after GTR does not reduce recurrence rate nor it changes significantly mean disease-free survival.

In cases of extradural SFTs/HPCs, no statistical difference in recurrence rate was observed among patients undergoing GTR ± RT versus STR ± RT ($P > 0.05$; $P = 0.2620$). Unlike intradural extramedullary tumors, adjuvant radiotherapy in patient with extradural SFTs/HPCs who underwent GTR increased mean disease-free survival, although it did not reduce recurrence rate.

A remarkably higher recurrence rate (51.5%) was observed in patients with vertebral (osseous) and intra/extradural/paravertebral SFTs/HPCs. The reason may be that en-bloc resection was not often feasible and piecemeal total resection is associated with the possibility of tumor cell contamination in the surgical field.

To date, all existing literature on primary spinal SFT/HPC is based

on retrospective studies. Given these limitations, it is not possible to make recommendations on the optimal management of primary spinal SFT/HPC. Randomized and prospective clinical trials are sorely needed, even if they are difficult to be conducted given the rarity of this disease.

6. Conclusion

Primary spinal SFTs/HPCs are extremely rare tumors with the tendency to recur. Multiple aspects should be taken into consideration in the diagnosis and treatment of these tumors. Successful treatment relies on careful preoperative planning, and on the choice of proper surgical procedure to prevent spinal cord injury, spinal instability and vascular hemorrhagic complications. Surgical treatment plays a crucial role in the management of spinal SFTs/HPCs and complete tumor resection should be attempted whenever possible.

Postsurgical radiotherapy does not reduce significantly recurrence rate after complete tumor resection, although it increases mean disease-free survival, especially in patients with extradural SFTs/HPCs.

Adjuvant radiotherapy is required after subtotal resection to reduce progression of disease.

Pathologic grade and total resection are the strong predictor factors for recurrence of these uncommon neoplasms. Regular and long-term follow-up is mandatory to monitor tumor recurrence.

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.

References

[1] A.P. Stout, M.R. Murray, Hemangiopericytoma: a vascular tumor featuring Zimmerman's pericytes, Ann. Surg. 116 (1) (1942) 26–33.

[2] P. Klemperer, C.B. Rabin, Primary neoplasm of the pleura: a report of five cases, Arch Pathol. 11 (1931) 385–412.

[3] D.N. Louis, A. Perry, G. Reifenberger, A. von Deimling, D. Figarella-Branger, W.K. Cavenee, et al., The 2016 World Health Organization classification of tumors of the central nervous system: a summary, Acta Neuropathol. 131 (6) (2016 Jun) 803–820.

[4] D. Fitzpatrick, J. Mahajan, M. Lewkowitz, K. Black, A. Setton, R. Woldenberg, Intradural hemangiopericytoma of the lumbar spine: a rare entity, AJNR Am. J. Neuroradiol. 30 (1) (2009) 152–154.

[5] J.H. Kim, H.W. Jung, Y.S. Kim, C.J. Kim, S.K. Hwang, S.H. Paek, et al., Meningeal hemangiopericytoms: long-term outcome and biological behavior, Surg. Neurol. 59 (1) (2003) 47–53.

[6] H. Dufour, P. Metellus, S. Fuentes, X. Murracciole, J. Régis, D. Figarella-Branger, et al., Meningeal hemangiopericytoma: a retrospective study of 21 patients with special review of postoperative external radiotherapy, Neurosurgery 48 (2001) 756–763.

[7] M. Nonaka, E. Kohmura, M. Hirata, T. Hayakawa, Metastatic meningeal hemangiopericytoma of thoracic spine, Clin. Neurol. Neurosurg. 100 (1998) 228–230.

[8] P.P. Kumar, R.R. Good, F.M. Skultety, A.S. Masih, R.D. McComb, Spinal metastases from pituitary hemangiopericytic meningioma, Am. J. Clin. Oncol. 10 (1987) 422–428.

[9] H. Liu, A. Yang, N. Chen, J. Yang, X.G. Qiu, J.G. Zhang, Hemangiopericytomas in the spine: clinical features, classification, treatment, and long-term follow-up in 26 patients, Neurosurgery 72 (2013) 16–24.

[10] T. Asazuma, Y. Toyama, H. Maruiwa, Y. Fujimura, Hira- bayashi K. Surgical strategy for cervical dumbbell tumors based on a three-dimensional classification, Spine 29 (2004) E10–E14.

[11] N.J. Espat, J.J. Lewis, D. Leung, et al., Conventional hemangiopericytoma: modern analysis of outcome, Cancer 95 (8) (2002) 1746–1751.

[12] P.C. Burger, B.W. Scheithauer, Tumors of the Central Nervous System in Atlas of Tumor Pathology, Series 4, Fascicle7, American Registry of Pathology and the Armed Forces Institute of Pathology, Washington, DC, 2007.

[13] C. Bouvier, P. Metellus, A.M. de Paula, A. Vasiljevic, A. Jouvet, J. Guyotat, et al., Solitary fibrous tumors and hemangiopericytomas of the meninges: overlapping pathological features and common prog- nostic factors suggest the same spectrum of tumors, Brain Pathol. 22 (2012) 511–521.

[14] J. Chmielecki, A.M. Crago, M. Rosenberg, R. O'Connor, S.R. Walker, L. Ambrogio, et al., Whole-exome sequencing identifies a recurrent NAB2-STAT6 fusion in solitary fibrous tumors, Nat. Genet. 45 (2013) 131–132.

[15] D.R. Robinson, Y.M. Wu, S. Kalyana-Sundaram, X. Cao, R.J. Lonigro, Y.S. Sung, et al., Identification of recurrent NAB2-STAT6 gene fusions in solitary fibrous tumor by integrative sequencing, Nat. Genet. 45 (2013) 180–185.

[16] X. Yi, D. Xiao, Y. He, H. Yin, G. Gong, X. Long, et al., Spinal solitary fibrous tumor/hemangiopericytoma: a clinicopathologic and radiologic analysis of eleven cases, World Neurosurg. 104 (2017) 318–329, https://doi.org/10.1016/j.wneu.2017.05.016.

[17] Z. Li, Y. Deng, Z. Li, T. Wang, J. Gao, W. Zhou, Y. Li, Y. Wang, Primary epidural hemangiopericytoma of the thoracic spine: case report and literature review, J. Clin. Neurosci. 60 (2019) 142–147.

[18] Q. Jia, Z. Zhou, D. Zhang, J. Yang, C. Liu, et al., Surgical management of spinal solitary fibrous tumor/hemangiopericytoma: a case series of 20 patients, Eur. Spine J. 27 (2018) 891–901, https://doi.org/10.1007/s00586-017-5376-0.

[19] D. Boyett, C.J. Kinslow, S.S. Bruce, A.M. Sonabend, et al., Spinal location is prognostic of survival for solitary-fibrous tumor/ hemangiopericytoma of the central nervous system, J. Neurooncol. 143 (2019) 457–464, https://doi.org/10.1007/s11060-019-03177-0.

[20] S. Boriani, J.N. Weinstein, R. Biagini, Primary bone tumors of the spine. Terminology and surgical staging, Spine 22 (9) (1997) 1036–1044.

[21] K. Ren, X. Zhou, S. Wu, et al., Primary osseous hemangiopericytoma in the thoracic spine, Clin. Neuropathol. 33 (5) (2014) 364–370.

[22] H. Chen, X.-W. Zeng, W. Jin-Song, et al., Solitary fibrous tumor of the central nervous system: a clinicopathologic study of 24 cases, Acta Neurochir. 154 (2) (2012) 237–248, https://doi.org/10.1007/s00701-011-1160-9.

[23] T. Onoki, H. Kanno, T. Aizawa, et al., Recurrent primary osseous hemangiopericytoma in the thoracic spine: a case report and literature review, Eur. Spine 27 (3) (2018) 386–392, https://doi.org/10.1007/s00586-017-5322-1.

[24] J. Wang, K. Zhao, L. Han, L. Jiao, W. Liu, Y. Xu, et al., Solitary fibrous tumor/hemangiopericytoma of spinal cord: a retrospective single-center study of 16 cases, World Neurosurg. 123 (2019 Mar) e629–e638, https://doi.org/10.1016/j.wneu.2018.12.004.

[25] A. Shirzadi, D. Drazin, M. Gates, N. Shirzadi, S. Bannykh, X. Fan, et al., Surgical management of primary spinal hemangiopericytomas: an institutional case series and review of the literature, Eur. Spine J. 22 (Suppl 3) (2013) S450–S459.

[26] M. Mohammadianpanah, S. Torabinejad, M.H. Bagheri, S. Omidvari, A. Mosalaei, N. Ahmadloo, Primary epidural malignant hemangiopericytoma of thoracic spinal column causing cord compression: case report, Sao Paulo Med. J. 122 (5) (2004) 220–222.

[27] A. Schirger, A. Uihlein, H.L. Parker, J.W. Kernohan, Hemangiopericytoma recurring after 26 years; report of case, Proc. Staff Meet Mayo Clin. 33 (13) (1958) 347–352.

[28] F. Kruse Jr, Hemangiopericytoma of the meninges (angioblastic meningioma of Cushing and Eisenhardt). Clinico-pathologic aspects and follow-up studies in 8 cases, Neurology 11 (1961) 771–777.

[29] P.J. Pitlyk, M.B. Dockery, R.H. Miller, Hemangiopericytoma of the spinal cord: report of three cases, Neurology 15 (1965) 649–653.

[30] F.C. Kriss, D.R. Kahn, R.C. Schneider, Value of angiography in intraspinal mediastinal hemangiopericytoma. Case report, J. Neurosurg. 29 (1968) 535–539.

[31] K. Fathie, Hemangiopericytoma of the thoracic spine; case report, J. Neurosurg. 32 (3) (1970) 371–374.

[32] R.E. Gerner, G.E. Moore, J.W. Pickren, Hemangiopericytoma, Ann. Surg. 179 (2) (1974) 128–132.

[33] M.J. McMaster, E.H. Soule, Ivins JC. Hemangiopericytoma, A clinicopathologic study and long-term follow-up of 60 patients, Cancer 36 (6) (1975) 2232–2244.

[34] D.J. Harris, V.L. Fornasier, K.E. Livingston, Hemangiopericytoma of the spinal canal. Report of three cases, J. Neurosurg. 49 (6) (1978) 914–920.

[35] M.B. Stern, M.L. Grode, M.D. Goodman, Hemangiopericytoma of the cervical spine: report of an unusual case, Clin. Orthop. Relat. Res. 151 (1980) 201–204.

[36] P. Cappabianca, F. Maiuri, G. Pettinato, B. Di Prisco, Hemangiopericytoma of the spinal canal, Surg. Neurol. 15 (4) (1981) 298–302.

[37] K.M. Muraszko, J.L. Antunes, S.K. Hilal, W.J. Michelsen, Hemangiopericytomas of the spine, Neurosurgery 10 (4) (1982) 473–479.

[38] P. Ciappetta, P. Celli, L. Palma, A. Mariottini, Intraspinal hemangiopericytomas. Report of two cases and review of the literature, Spine 10 (1) (1985) 27–31.

[39] L.R. Bridges, S. Roche, L. Nashef, F.C. Rose, Haemangiopericytic meningioma of the sacral canal: a case report, J. Neurol. Neurosurg. Psychiatry 51 (2) (1988) 288–290.

[40] M. Salvati, P. Ciappetta, M. Artico, A. Raco, A. Fortuna, Intraspinal hemangiopericytoma: case report and review of the literature, Neurosurg. Rev. 14 (4) (1991) 309–313.

[41] S.S. Carneiro, B.W. Scheithauer, A.G. Nascimento, T. Hirose, D.H. Davis, Solitary fibrous tumor of the meninges: a lesion distinct from fibrous meningioma. A clinicopathologic and immunohisto- chemical study, Am. J. Clin. Pathol. 106 (1996) 217–224.

[42] S.R. Alston, P.C. Francel, J.A. Jane Jr, Solitary fibrous tumor of the spinal cord, Am. J. Surg. Pathol. 21 (1997) 477–483.

[43] A.M. Malek, S.J. Weller, D.L. Price Jret al., Solitary fibrous tumor presenting as a symptomatic spinal mass, Neurosurgery 40 (1997) 844–847.

[44] A. Brunori, S. Cerasoli, R. Donati, et al., Solitary fibrous tumor of the meninges: two new cases and review of the literature, Surg Neurol. 51 (1999) 636–640.

[45] T. Kanahara, M. Hirokawa, M. Shimizu, et al., Solitary fibrous tumor of the spinal cord. Report of a case with scrape cytology, Acta Cytol. 43 (1999) 425–428.

[46] H. Kataoka, Y. Akiyama, S. Kubo, H. Itoh, et al., Solitary fibrous tumor of the spinal nerve rootlet: Case report and literature survey, Pathol. Int. 49 (1999) 826–830.

[47] S.J. Vorster, R.A. Prayson, J.H. Lee, Solitary fibrous tumor of the thoracic spine. Case report and review of the literature, J. Neurosurg. 92 (2000) 217–220(suppl).

[48] J.P. Mordani, I.U. Haq, J. Singh, Solitary fibrous tumor of the spinal cord, Neuroradiology 42 (2000) 679–681.

[49] P.D. Ackerman, A. Khaldi, J.F. Shea, Intradural hemangiopericytoma of the thoracic spine: a case report, Spine J. 11 (7) (2011) e9–e14.

[50] O. Kurtkaya, I. Elmaci, A. Sav, M. Pamir, Spinal solitary fibrous tumor: seventh reported case and review of the literature, Spinal Cord. 39 (2001) 57–60.
[51] A. Akhaddar, N. Chakir, A. Amarti, M.R. El Hassani, A. El Khamlichi, M. Jiddane, Thoracic epidural hemangiopericytoma. Case report, J. Neurosurg. Sci. 46 (2) (2002) 89–92.
[52] S. Betchen, A. Schwartz, C. Black, K. Post, Intradural hemangiopericytoma of the lumbar spine: case report, Neurosurgery 50 (3) (2002) 654–657.
[53] K. Ijiri, S. Yuasa, K. Yone, S. Matsunaga, Y. Ryoki, N. Taniguchi, et al. Primary epidural hemangiopericytoma in the lumbar spine: a case report. Spine (Phila Pa 1976) 27 (7) (2002) E189–E192.
[54] K. Endo, M. Komagata, H. Ikegami, M. Nishiyama, et al., Dumbbell-type solitary fibrous tumor in the cervical spine, J. Orthop. Sci. 8 (2003) 428–431.
[55] R.J. Bohinski, E. Mendel, K.D. Aldape, L.D. Rhines, Intramedullary and extramedullary solitary fibrous tumor of the cervical spine. Case report and review of the literature, J. Neurosurg. 100 (2004) 358–363.
[56] S. Pizzolitto, G. Falconieri, G. Demaglio, Solitary fibrous tumor of the spinal cord: a clinicopathologic study of two cases, Ann. Diagn. Pathol. 8 (2004) 268–275.
[57] S. Piana, I. Putrino, A. Cavazza, E. Nigrisoli, Solitary fibrous tumor of the spinal nerve rootlet: report of a case mimicking schwannoma, Arch. Pathol. Lab. Med. 128 (3) (2004) 335–337.
[58] G.I. Jallo, C. Roonprapunt, K. Kothbauer, D. Freed, J. Allen, F. Epstein, Spinal solitary fibrous tumors: a series of four patients: case report, Neurosurgery 57 (2005) E195.
[59] D. Kashiwazaki, K. Hida, S. Yano, T. Seki, Y. Iwasaki, Subpial hemangiopericytoma with marked extramedullary growth: case report, Neurosurgery 61 (6) (2007) E1336–E1337.
[60] R. Kumar, V.K. Vaid, V. Kumar, S.K. Kalra, Hemangiopericytoma of thoracic spine: a rare bony tumor, Childs Nerv. Syst. 23 (10) (2007) 1215–1219.
[61] Y. Zhao, J.Z. Zhao, Clinical and pathological characteristics of primary intraspinal hemangiopericytoma and choice of treatment, Chin. Med. J. (Engl). 120 (2) (2007) 115–119.
[62] C.W. Chou, S.P. Hsu, S.C. Lin, M.H. Chen, Y.H. Shih, L.S. Lee, et al., Primary intradural hemangiopericytoma with intramedullary invasion, J. Chin. Med. Assoc. 72 (10) (2009) 536–541.
[63] H. Kakimaru, M. Matsusaki, H. Sanada, A. Iwata, Y. Uchio, Dumbbell-type spinal solitary fibrous tumor with paraplegia, Orthopedics 32 (3) (2009 Mar) 213.
[64] P. Ciappetta, P.I. D'Urso, A. Cimmino, G. Ingravallo, R. Rossi, A. Colamaria, O.F. D'Urso, Intramedullary solitary fibrous tumor of dorsal spinal cord, Neuropathology 30 (2010) 273–278.
[65] K. Ishii, M. Nakamura, M. Matsumoto, M. Mukai, et al., Intramedullary solitary fibrous tumor of the spinal cord, Journal of Orthopaedic Science 14 (2009) 450–454.
[66] K.M. Fargen, K.J. Opalach, D. Wakefield, R.P. Jacob, A.T. Yachnis, J.R. Lister, The central nervous system solitary fibrous tumor: a review of clinical, imaging and pathologic findings among all reported cases from 1996 to 2010, Clin. Neurol. Neurosurg. 113 (2011) 703–710.
[67] S. Moscovici, F. Ramirez-DeNoriega, Y. Fellig, G. Rosenthal, J.E. Cohen, E. Itshayek, Intradural extramedullary hemangiopericytoma of the thoracic spine infiltrating a nerve root: a case report and literature review, Spine (Phila Pa 1976) 36 (23) (2011) 1534–1539.
[68] A. Santillan, W. Zink, E. Lavi, J. Boockvar, Y.P. Gobin, A. Patsalides, Endovascular embolization of cervical hemangiopericytoma with Onyx-18: case report and review of the literature, J. Neurointerv. Surg. 3 (3) (2011) 304–307.
[69] M. Brigui, S. Aldea, M. Bernier, S. Bennis, et al., Two patients with a solitary fibrous tumor of the thoracic spinal cord, J. Clin. Neurosci. 20 (2013) 317–319.
[70] G. Mariniello, M. Napoli, C. Russo, F. Briganti, A. Giamundo, et al., MRI features of spinal solitary fibrous tumors. A report of two cases and literature review, Neuroradiol. J. 25 (2012) 610–616.
[71] K. Torigoe, T. Akai, T. Iida, Hemangiopericytoma on the intradural thoracic spinal cord: a case report, No Shinkei Geka 40 (4) (2012) 351–357.
[72] H. Nakashima, S. Imagama, Y. Sakai, H. Nakamura, Y. Katayama, Z. Ito, et al., Dumbbell-type hemangiopericytoma in the cervical spine: a case report and review, J. Orthop. Sci. 18 (2013) 849–855.
[73] D. Drazin, F. Shweikeh, S. Bannykh, J.P. Johnson, Hemangiopericytoma invading the craniovertebral junction: first reported case and review of the literature, J. Craniovertebr. Junction Spine 4 (2013) 32–34.
[74] C.H. Lee, K.J. Kim, T.A. Jahng, H.J. Kim, Spinal hemangiopericytoma which needed intraoperative embolization due to unexpected bleeding, J. Korean Neurosurg. Soc. 54 (3) (2013) 253–256.
[75] P. Zhang, J. Hu, D. Zhou, Hemangiopericytoma of the cervicothoracic spine: a case report and literature review, Turk Neurosurg. 24 (6) (2014) 948–953.
[76] V. Ramdasi Raghvendra, D. Nadkarni Trimurti, Naina A. Goel, Hemangiopericytoma of the cervical spine, J. Craniovertebr. J. Spine 5 (2) (2014) 95–98.
[77] E. Jayashankar, S. Prabhala, S. Raju, R. Tanikella, Recurrent extradural hemangiopericytoma of thoracic spine: a case report, Indian J. Pathol. Microbiol. 57 (4) (2014) 603–605.
[78] J. Kaur, S. Pandit, M.C. Sharma, P.K. Julka, G.K. Rath, Intradural extra medullary hemangiopericytoma of dorsal spine, Childs Nerv. Syst. 31 (1) (2015) 173–175.
[79] T. Robert, C. Duc, D. San Millan Ruiz, M. Morard, Solitary fibrous tumour with intramedullary component: case report and review of the literature, Neurol. Neurochir. Pol. 48 (2014) 144–149.
[80] J.P. Lavrador, E. Oliveira, L. Neto, J. Pimentel, A.F. Francisco, et al., Dumbbell-shaped spinal solitary fibrous tumor: combined approach and a review of the literature, Neurochirurgie 61 (2015) 287–291, https://doi.org/10.1016/j.neuchi.2015.03.006.
[81] C.Ç. Türk, N.N. Kara, D. Süren, Ç. Özdöl, T. Gediz, S. Yıldız, Distinctive characteristic features of intramedullary hemangiopericytomas, Asian Spine J. 9 (4) (2015) 522–528.
[82] A. Das, P. Singh, V. Suri, M.N. Sable, B.S. Sharma, Spinal hemangiopericytoma: an institutional experience and review of the literature, Eur. Spine J. 24 (2015) 606–613.
[83] L.S. Chew, X.J. Han, K.K. Tan, M.M. Bundele, Hemangiopericytoma of the thoracic spine: a case report, J. Surg. Case Rep. 7 (2017) 1–4.
[84] H. Wang, L. Wang, Y. Lu, C. Lu, T. Xu, Y. Yan, J. Chen, Remarkable recovery in a patient with intradural extramedullary haemangiopericytoma: a case report and literature review, Folia Neuropathol. 56 (2) (2018) 151–157.
[85] Y.W. Zhang, Q. Xiao, J. Zeng, L. Deng, Solitary fibrous tumor of the lumbar spine resembling Schwannoma: case report and review of the literature, World Neurosurg. 124 (2019) 121–124.