ORIGINAL ARTICLE

Retrospective institutional study of 31 patients treated for pulmonary artery sarcoma[†]

Sacha Mussot[a,*], Maria-Rosa Ghigna[a], Olaf Mercier[a], Dominique Fabre[a], Elie Fadel[a], Axel Le Cesne[b], Gerald Simonneau[c] and Philippe Dartevelle[a]

[a] Department of Thoracic & Vascular Surgery and Heart-Lung Transplantation, Marie Lannelongue Hospital, Paris-Sud University, Le Plessis Robinson, France
[b] Department of Medicine, Sarcoma Unit, Gustave Roussy Institute, Paris Sud University, Villejuif cedex, France
[c] National Reference Center for Severe Pulmonary Hypertension, Department of Pneumology, INSERM U999, Antoine Béclère Hospital, Clamart, France

* Corresponding author. Department of Thoracic & Vascular Surgery and Heart-Lung Transplantation, Marie Lannelongue Hospital, 133, Avenue de la Résistance, 92350 Le Plessis Robinson, France. Tel: +331-4094-8568; fax: +33-1-40948804; e-mail: s.mussot@ccml.fr (S. Mussot).

Abstract

OBJECTIVES: The study aimed to determine the optimal surgical procedure to treat pulmonary artery sarcomas responsible for pulmonary hypertension.

METHODS: Between 1997 and 2010, 31 patients were treated surgically for pulmonary artery sarcomas. Sixteen patients were male; the mean age was 56 years (range, 26–78 years). Common symptoms were characteristic of acute or chronic pulmonary thromboembolic disease. Also, 21 patients experienced mild to severe pulmonary hypertension, with a mean total peripheral resistance of 473 dyn s cm^{-5}. Clinical presentation and preoperative work-up confirmed the suspicion of pulmonary artery sarcoma in 18 patients. The required surgical procedures included the following: pulmonary endarterectomy in 25 patients (combined with a right pneumonectomy in five and with a replacement of the main pulmonary artery by a homograft reconstruction in one), pneumonectomy only in five (three right and two left), with the use of cardiopulmonary bypass in three cases. In one patient, the right pulmonary artery only was replaced on cardiopulmonary bypass.

RESULTS: Final pathology showed 26 high-grade and five intermediate-grade sarcomas. The 30-day mortality was 13% (four patients). Repeat pulmonary resection was required in two patients due to recurrent disease. Moreover, 18 patients received adjuvant therapy. Mean follow-up was 19 months (range, 1–99 months); of the 11 patients alive at follow-up, four were noted to have recurrent disease. The 1-, 3- and 5- year survival was 63, 29 and 22%, respectively.

CONCLUSIONS: The prognosis of this very infrequent disease remains poor. Bilateral pulmonary endarterectomy may yield significant survival rates because it provides completeness of resection without sacrificing the pulmonary vascular bed.

Keywords: Sarcoma · Pulmonary arterial hypertension · Pulmonary thromboendarterectomy · Cancer

INTRODUCTION

Primary pulmonary artery sarcoma (PAS) is a rare thoracic tumour of unknown aetiology and dismal prognosis. The first autoptic description was reported by Mandelstamm in 1923 [1]. Since then, approximately 200 cases have been described [2], mostly as case reports. The incidence of this orphan disease is 0.001–0.03%, but it must be underestimated because PAS frequently mimics pulmonary vascular diseases, such as acute pulmonary embolism, chronic thromboembolic pulmonary hypertension (CTEPH) and primary pulmonary hypertension. Early diagnosis is always difficult, albeit pathological classifications have evolved over time. Descriptions prior to 1975 are confusing and should be interpreted cautiously. As a rule, it is

disease of adulthood, but some cases in children have been reported [3].

Owing to the limited number of cases, there are very few small case series describing the management of these tumours [4–8]. Interestingly, the largest series have been reported by pathologists [9, 10].

We report our experience with the surgical management of this rare disease.

MATERIALS AND METHODS

We retrospectively reviewed the clinical records of all patients who could be identified through a computer-assisted search of all medical records with a pathological diagnosis of PAS, primarily diagnosed at the Marie Lannelongue Hospital. Between January 1997 and December 2010, a total of 31 patients

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underwent operations for PAS at our institution. In all instances, the operations were performed with curative intent. The medical records were retrospectively reviewed to evaluate the clinical characteristics, operative findings, the postoperative outcomes and the long-term results.

We excluded from this study: (i) patients with lung parenchymal sarcomas; (ii) patients with metastatic sarcomas of the pulmonary vessels (e.g. non-primary pulmonary artery sarcomas); and (iii) patients with inoperable primary pulmonary artery sarcomas in a fully palliative situation.

All patients were contacted by telephone interview or direct consultation if a progression of the disease was suspected.

Clinical characteristics

There were 16 male and 15 female patients, with a mean age of 56 years (range, 26–78 years). Most of the 31 patients experienced common symptoms of acute or chronic pulmonary thromboembolic disease, including severe progressive or acute dyspnoea (New York Heart Association class III/IV, $n = 4/22$), chest pain ($n = 4$), fever ($n = 3$) and syncope ($n = 1$).

Owing to an unstable haemodynamic condition, three patients underwent surgery on an emergency basis and could not benefit from a complete preoperative work-up; nethertheless, they all had blood tests, chest X-ray, computed tomography (CT) scan and cardiac echography. The remaining 28 underwent chest X-ray, where a metastatic disease was suspected in two cases, with stigmata of pulmonary hypertension (PH) demonstrated in five.

Ventilation–perfusion scintiscan ($n = 21$), showing in most cases a mismatch between a normal or subnormal ventilation and a strongly altered perfusion, and computed tomography of the chest ($n = 31$) were the main components in the diagnostic work-up of PAS. Chest CT demonstrated the presence of a large quantity of endoluminal material proximally in the main pulmonary artery, involvement of the pulmonary valve (one patient; Fig. 1), mild contrast enhancement of the intravascular mass ($n = 5$) or extravascular spreading of the lesion ($n = 2$).

Magnetic resonance imaging was of some help in analysing the endovascular component of the tumour in four patients. In 21 patients, the main feature of transthoracic echocardiography ($n = 31$) was the presence of pulmonary hypertension, whereas infiltration of the pulmonary valve was detected in only one case.

Pulmonary angiograms were obtained in 18 patients and confirmed pulmonary hypertension in 10, with a mean total vascular pulmonary resistance of 473 dyn/s/cm^5 (range, 215–947 dyn/s/cm^5). In addition, pulmonary angiograms demonstrated or strongly suggested the diagnosis of an intravascular malignant tumour in eight patients showing complete occlusion of the pulmonary artery or vascular parietal alterations (Fig. 2).

Since 2006, 12 patients have been subjected to F-18 fluoro-deoxyglucose positron emission tomography with integrated computed tomography (FDG-PET/CT), yielding positive lesions in 10 (Fig. 3).

A biopsy of the mediastinal lesion was attempted in three patients, either CT guided (in another institution) or via the endovascular route, and yielded a diagnosis of PAS in two patients.

Table 1 summarizes the initial diagnosis on referral for the 31 patients and the timing of the correct PAS diagnosis.
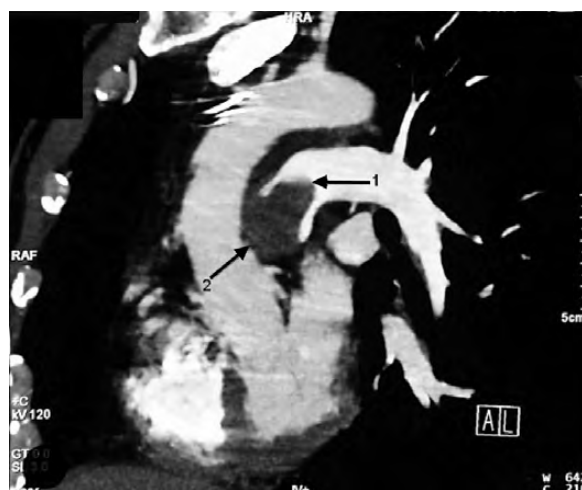

Figure 1: Pulmonary artery sarcomas in a 55-year old man with dyspnoea class II–III wrongly diagnosed as chronic thromboembolic pulmonary hypertension (CTEPH). Coronal enhanced computed tomography shows a filling defect occupying nearly the entire lumen of the main pulmonary artery (arrow 1), involving the pulmonary valves (arrow 2) and extending into the origin of left pulmonary artery (patient no. 8).
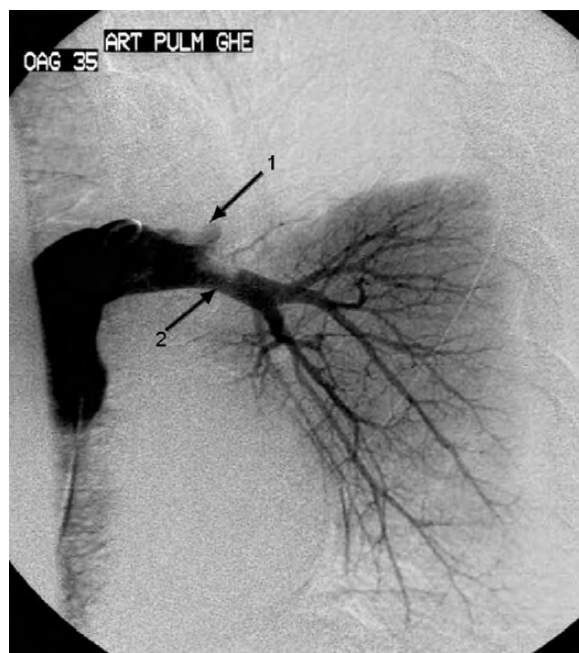

Figure 2: Pulmonary artery sarcomas in a 78-year old man with dyspnoea class III wrongly diagnosed as CTEPH (patient no. 6). Pulmonary angiogram showing irregular occlusion of left upper lobe arteries (arrow 1), with endoluminal material in the left lower lobe artery (arrow 2). Note the absence of left upper lobe parenchymal opacification.

Surgical procedures (Table 2)

An angioscopic video-assisted pulmonary endarterectomy (PE) was performed in 25 patients and it was combined with a right pneumonectomy in five patients and a homograft reconstruction of the main pulmonary artery in one.

The technical details of PE are similar to the surgery for CTEPH as originally described by Dartevelle *et al.* [11].
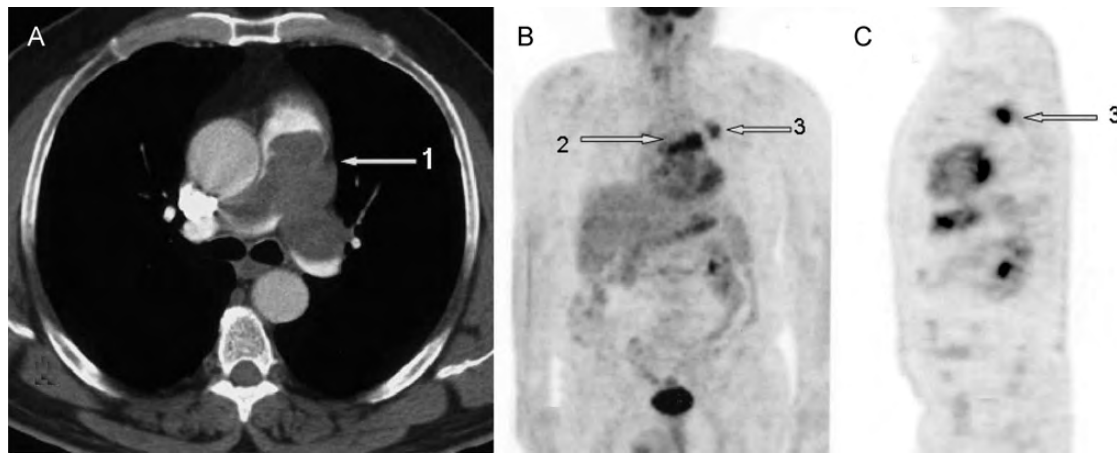
Figure 3: Pulmonary artery sarcomas in a 62-year-old man with acute dyspnoea wrongly diagnosed as acute pulmonary embolism (patient no.30). (**A**) Axial enhanced computed tomography shows filling defect occupying nearly the entire lumen of the main pulmonary artery (arrow 1) and extending into the origin of both pulmonary arteries. (**B** and **C**) F-18 fluorodeoxyglucose positron emission tomography with integrated computed tomography (FDG-PET/CT) showing intense hypermetabolism in the main pulmonary artery (arrow 2), in the origin of the right and left pulmonary arteries and in the left upper lobe (metastasis; arrow 3).

Table 1: Initial diagnosis on referral for the 31 patients and timing of the correct diagnosis

Patient no.	Sex	Age (years)	Initial diagnosis before evaluation at MLH	HPS or PPD	PE or FS
1	M	44	CTEPH		PE
2	F	28	CTEPH		PE
3	M	63	CTEPH		PE
4	M	48	CTEPH		PE
5	M	67	CTEPH		PE
6	M	78	CTEPH		FS
7	M	55	CTEPH	HPS	
8	F	53	CTEPH	HPS	
9	F	58	PAS	HPS	
10	F	53	CTEPH	HPS	
11	F	48	CTEPH	HPS	
12	F	52	PAS	PPD	
13	F	53	CTEPH	HPS	
14	F	54	CTEPH	HPS	
15	M	73	CTEPH	PPD	
16	F	53	PAS	PPD	
17	M	35	PAS + lung metastasis	PPD	
18	M	69	PAS + lung metastasis	HPS	
19	F	66	APE	HPS	
20	F	26	CTEPH	HPS	
21	M	73	APE	HPS	
22	F	55	CTEPH	PPD	
23	F	68	Fibrosing mediastinitis		FS
24	F	70	Infectious pneumonia	HPS	
25	F	73	APE	HPS	
26	M	56	APE	HPS	
27	F	64	Infectious pneumonia	HPS	
28	M	75	PAS	HPS	
29	M	62	APE		FS
30	M	47	APE	HPS	
31	M	35	PAS	HPS	

APE: acute pulmonary embolism; CTEPH: chronic thromboembolic pulmonary hypertension; F: female; FS: intraoperative frozen section pathological diagnosis; HPS: high preoperative suspicion; M: male; MLH: Marie Lannelongue Hospital; PAS: pulmonary artrey sarcoma; PE: paraffin-embedded pathological postoperative diagnosis; PPD: preoperative pathological diagnosis.

Angioscopic video-assisted pulmonary endarterectomy is performed during circulatory arrest under deep hypothermia (18°C), with the intention of removing neoplastic obstructive material from each pulmonary artery and its lobar or segmental branches. The use of a 5-mm videothoracoscope gives much better visibility of the operative field for the senior surgeon and offers high-quality indirect two-dimensional vision to his assistants. In order to completely excise the PAS, even more than in CTEPH, a true endarterectomy is required, starting at the level of the intrapericardial right and left pulmonary arteries and progressively extending distally into each of the branches of the pulmonary artery tree (Fig. 4). As in CTEPH, patients with PAS develop a significant systemic collateral neovascularization from bronchial arteries resulting, in significant back-bleeding from the pulmonary artery at the time of endarterectomy. The only way to stop this bleeding, which continuously fills the pulmonary artery and pools in the surgical field, is to arrest the systemic circulation under deep hypothermia (18–20°C). In order to reduce the time of circulatory arrest, cardiopulmonary bypass is stopped only after identification of the correct plane for endarterectomy. After completion of endarterectomy on the first side, the extracorporeal circulation is resumed for about 15 min before the contralateral endarterectomy is performed. In our series, the mean bypass time and cross-clamp time were 204 and 76 min, respectively; intermittent circulatory arrest was required in 18 patients (mean, 14 min).

A pneumonectomy was necessary in five patients (three right and two left); the procedure was completed on cardiopulmonary bypass in three patients and was associated with a coronary artery bypass in one.

An intrapericardial pneumonectomy was performed in 10 patients. Of these procedures, nine were done through a median sternotomy. In five patients, intrapericardial pneumonectomy was combined with endarterectomy, whereas the main pulmonary artery needed to be reconstructed under bypass using bovine pericardium in two patients and a valved prosthetic tube in one. In one patient, a pneumonectomy was done through left thoracotomy off bypass. Finally, the right pulmonary artery only was replaced on cardiopulmonary bypass in one patient.

Table 2:   Surgical procedures for the 31 patients

Patient no.	Operative procedures	Use of CPB	Emergency	Complete resection	Adjuvant treatment
1	PE	Yes	No	Yes	None
2	PE	Yes	No	Yes	CT
3	PE	Yes	Yes	Yes	NA
4	PE	Yes	No	Yes	CT
5	PE + RP	Yes	No	No	NA
6	PE + RP	Yes	No	Yes	CT
7	PE, MPA reconstruction	Yes	No	Yes	CT
8	PE	Yes	No	Yes	RT
9	RP, MPA reconstruction	Yes	No	Yes	CT
10	PE	PE	No	Yes	CT
11	PE	PE	No	Yes	None
12	RP	No	No	Yes	None
13	PE	Yes	No	Yes	None
14	PE	Yes	No	Yes	CT
15	PE	Yes	No	No	NA
16	RPA resection	Yes	No	No	CT
17	PE	Yes	No	Yes	CT
18	PE	Yes	No	No	CT
19	PE	Yes	Yes	No	CT
20	PE	Yes	No	No	RT
21	PE	Yes	No	No	CT
22	PE + RP	Yes	No	No	CT
23	PE	Yes	Yes	Yes	None
24	LP	No	No	Yes	None
25	PE	Yes	No	No	None
26	LP	Yes	No	No	None
27	PE	Yes	No	Yes	CT + RT
28	RP, pericardial patch, CABG	Yes	No	Yes	NA
29	PE	Yes	No	No	None
30	PE + RP, pericardial patch	Yes	No	Yes	CT
31	PE + RP	Yes	No	No	CT

CABG: coronary artery bypass graft; CBP: cardiopulmonary bypass; CT: chemotherapy; LP: left pneumonectomy; MPA: main pulmonary artery; NA: not applicable; PE: pulmonary endarterectomy; RP: right pneumonectomy; RPA: right pulmonary artery; RT: radiotherapy.

Pathological examination

Paraffin-embedded tissue specimens were available in all 31 cases, and immunohistochemical stains for cytokeratins, S-100 protein, desmin and smooth muscle actin were performed.

Histology and grading were assessed according to the 2004 World Health Orgamization Classification of soft tissue tumours and Fédération Nationale des Centres de Lutte Contre le Cancer grading system.

RESULTS

Pathological results

An intraoperative frozen section was done routinely when a pneumonectomy (alone or associated with PE) was considered mandatory. Positive margins were detected in three cases following right pneumonectomy and endarterectomy and in one after pneumonectomy alone. The only patient with an isolated replacement of the right pulmonary artery had both proximal and distal positive margins.

Final pathology was available for all patients. twenty-six specimens were classified as high-grade sarcoma, including Malignant Fibrous Histiocytoma type pleomorphic fascicular sarcoma ($n = 18$), leiomyosarcoma ($n = 4$), high-grade sarcoma with prominent myxoid changes ($n = 2$), poorly differentiated sarcoma with osteosarcomatous differentiation ($n = 1$) and sarcoma with chondrosarcomatous differentiation ($n = 1$). A smaller group of specimens were diagnosed as intermediate-grade intimal sarcoma and included two leiomyosarcomas and three spindle cell sarcomas.

Histologically high-grade fascicular sarcoma consisted of storiform proliferation of spindle/pleomorphic cells, negative or focally positive for smooth-muscle actin and not expressing other markers, such as pancytokeratin, desmin and S-100 protein. Leiomyosarcomas were composed of spindle cells arranged in a fascicular pattern, expressing smooth-muscle actin and desmin. Sarcomas with osteosarcomatous or chondrosarcomatous differentiation had a prominent MFH-like background, respectively admixed with woven bone trabeculae and immature cartilage. The high-grade myxofibrosarcoma was characterized by prominent myxoid changes, harbouring myofibroblast-like cells (presenting with vesicular nuclei encircled by abundant eosinophilic cytoplasm) and some inflammatory cells and necrosis.

No significant difference emerged in survival according to histological type, and no sex predilection was noticed for any of the categories.
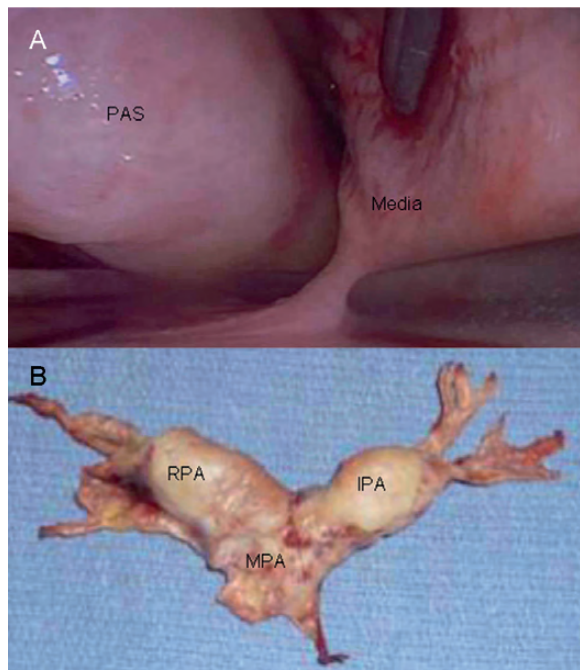
Figure 4: Pulmonary artery sarcomas in a 68-year old woman with dyspnoea class IV wrongly diagnosed as fibrosing mediastinitis (patient no. 23). (A) intraoperative view (video-assisted) showing the tumour (PAS) progressively freed from the internal part of the media of the right pulmonary artery. (B) Resected specimen of leiomyosarcoma grade II with main pulmonary artery (MPA), right pulmonary artery (RPA) and left pulmonary artery (LPA) as a cast of the arterial tree with its segmental and subsegmental branches.

Clinical results

The 30-day mortality rate was 13% (four patients). Causes of death included massive pulmonary embolism in one patient, failure to wean from bypass in one and adult respiratory distress syndrome following right pneumonectomy in the remaining two patients. Furthermore, two patients experienced bleeding that required reoperation following right pneumonectomy.

Owing to the very poor prognosis of these sarcomas that were at least of intermediate grade and in the majority of the patients ($n = 26$) of high grade, the nearly constant metastatic evolution and the surgical resection that is by definition nearly never R0, an adjuvant therapy is mandatory every time when the age and performance status of the patient allowed it. Eighteen patients received adjuvant therapy as follows: chemotherapy ($n = 15$); radiotherapy ($n = 2$); or both ($n = 1$). Moreover, six patients had neoadjuvant chemotherapy.

Follow-up was completed for all the patients with a mean duration of 19 months (range, 1–99 months). During follow-up, 20 patients died after a median survival time of 17 months (mean, 20.6 months). The cause of death was related to the recurrence of PAS in all cases.

Among the 11 patients alive at follow-up, seven had no recurrence. In the four patients noted to have recurrent disease, two were reoperated as follows: one had parenchymal metastatic recurrences treated by wedge resections once; the other was reoperated twice for wedge resections and once for a pleural metastasis.

Cumulative survival rates according to the Kaplan–Meier method at 1, 3 and 5 years were 63, 29 and 22%, respectively (Fig. 5). The 20 patients treated by PE alone seemed to have a
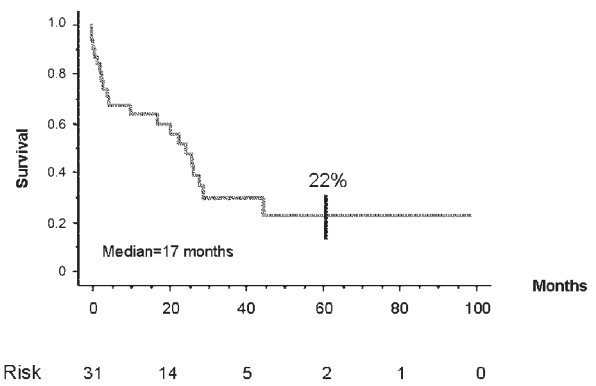

Figure 5: Statistical cumulative survival (Kaplan–Meier estimator) showing 1, 3 and 5 year survival of the 31 patients.

longer survival when compared with the remaining 11, although the difference was not statistically significant.

DISCUSSION

In one of the largest single-centre experiences of primary malignant sarcomas of the heart and great vessels collected over 13 years, there were only two PAS out of 1429 patients [12], i.e. <1%. In addition to the rarity of this disease, the symptoms are insidious and non-specific, making an early diagnosis challenging. The majority of the cases reported in the literature have been identified at autopsy [13]. Primary pulmonary artery sarcoma is likely to be mistaken for chronic or acute pulmonary thromboembolism, because most of the time the clinical manifestations of PAS are remarkably similar to those of CTEPH. Indeed, in our series, the initial diagnosis was CTEPH in 15 patients and acute pulmonary embolism in six (Table 1). In fact, the differential diagnosis includes all the causes of obstructive pulmonary hypertension, namely pulmonary arteritis (Behçet disease, Takayashu disease), primary lung cancer, mediastinal tumours, tumour emboli into the pulmonary artery (from extrathoracic cancers), hydatic emboli and fibrosing mediastinitis. After an extensive evaluation, the diagnosis of PAS was proved or highly suspected in 23 patients but, as in the series by Anderson *et al.* [8], the mean delay between the beginning of symptoms and final diagnosis was more than a year.

Right heart catheterization is done during the angiography and results were available for 18 patients. In PAS, there is usually a mismatch between the importance of vascular obstruction and the severity of pulmonary hypertension; thus, the mean total peripheral resistance was 473 dyn s /cm^5. One hypothesis is that this disease has a more rapid progression of obstruction compared with CTEPH and because of that the right ventricle is less likely to generate such high pulmonary hypertension. The last aspect of right heart catheterization is the possibility to obtain an endovascular catheter biopsy, which we have done twice with one success. It is a demanding and dangerous procedure that requires a highly skilled vascular radiologist trained to deal with pulmonary hypertension. Henceforth, we will use this option when surgery is contraindicated. Enhanced computed tomography is the other key examination; even if it is difficult to differentiate between a clot and a tumour, the association of irregular endoluminal stenosis with a solid mass arising from the pulmonary valve and extending into one or both pulmonary arteries is again nearly pathognomonic. F-18 fluorodeoxyglucose PET/CT is

a new tool (since 2006 in our series) [14, 15] and was available for 12 patients, demonstrating hypermetabolism in 10. The two patients (nos. 19 and 21) with negative FDG imaging both had important endoluminal tumours treated by pulmonary endarterectomy. Pathology proved that both of them were intimal sarcomas of grade III. The patient with undifferentiated MFH died at 1.5 months and the other, with a differentiated leiomyosarcoma, is alive at 43 months with lung metastasis.

There is some heterogeneity in the histological classification of lung artery sarcoma, depending merely on the pathologist. While some authors emphasize the intimal origin of sarcomas in their reports, others use the World Health Organization soft tissue tumours classification [16].

Although no correlation between histology and prognosis was observed in our series, some authors recently described a low-grade sarcoma subset with myofibroblastic morphology, associated with satisfactory long-term follow-up [9]. For this reason, the histology should be carefully assessed on an individual basis, given the challenging surgical procedure needed to remove PAS.

Primary pulmonary artery sarcoma is a proximal and diffuse disease arising within the main pulmonary artery or the pulmonary valve region. The tumour may extend distally along the intima in the direction of the blood flow or proximally into the right ventricular outflow. In time, the tumour will invade the pulmonary valve or the right ventricular outflow tract. Bleisch and Kraus [17] found that in 60 patients with PAS the main pulmonary artery was involved in 100% of the patients, the pulmonary valve in 57%, the right ventricle in 25%, the right pulmonary artery in 67% and the left pulmonary artery in 60%. Accordingly, early management of this aggressive disease is mandatory, and a surgical option must be contemplated [18, 19]. At first, the gold standard was pneumonectomy through thoracotomy [20]; however, as these tumours arise from the intima of the pulmonary artery, are proximal and tend to extend in a centrifugal manner, invading surrounding structures, radical resection via a sternotomy under cardiopulmonary bypass is required. Moreover, pulmonary endarterectomy under deep hypothermia and circulatory arrest is the treatment of choice every time when it is possible, because it may result in complete tumour removal. One problem is to evaluate the completeness of excision in PE alone. In our series, the 20 PE (without associated pneumonectomy) were macroscopically radical excisions except for patient no. 20, who is alive at 61 months with no recurrence. There was no significant statistical difference in the survival of the patients whatever surgery was performed, but we noticed a trend for better survival in the PE group. As a consequence, we believe that pulmonary endarterectomy, even in the setting of an extensive disease, can provide excellent palliative therapy because it preserves the pulmonary vascular bed and delays the inevitable recurrence of pulmonary hypertension brought about by neoplastic obstruction. Heart-lung transplantation has been performed twice in the literature for PAS with little success. The patient described by Britton [21] died at 5 months of sepsis, but the autopsy indentified metastatic disease; the other patient, from the series of Chhaya et al. [22] died at 5 months of disseminated metastasis. Nevertheless, this option has to be discussed with young patients who have neither extrathoracic nor pleural disease, when pulmonary endarterectomy obviously becomes a palliative option. We had on the waiting list for heart-lung transplantation two patients with PAS and concomitant bilateral lung metastasis who finally died of PAS before they could receive heart-lung transplantation [23].

In the literature, the median survival time without surgical resection is 45 days, whereas it is 10 months with surgery [13]. As the prognosis of these tumours depends on local recurrence and on metastatic dissemination, adjuvant therapy including the combination of chemotherapy and radiotherapy needs to be discussed with each individual patient. In our series, 66% of the patients who survived surgery received an adjuvant therapy, with no significant statistical difference in survival when we compared the two groups with or without adjuvant therapy. A preclinical model of lung metastatic sarcoma using pulmonary artery perfusion of doxorubicin with blood flow occlusion has been described to possess important pharmacokinetic advantages and an increased treatment response [24].

In summary, early diagnosis of this uncommon cancer is an essential prerequisite to allow for radical surgical management by angioscopic video-assisted pulmonary endarterectomy. Surgery has to be integrated in a multidisciplinary pathway of care, along with chemotherapy, radiotherapy or both. Basic and clinical research are mandatory to improve the outcome of these combined treatments and the survival of these patients.

Conflict of interest: none declared.

REFERENCES

[1] Mandelstamm M. Über primäre Neubildungen des Herzens. Virchows Arch Pathol Anat 1923;245:43–54.
[2] Levy E, Korach A, Amir G, Milgalter E. Undifferentiated sarcoma of the pulmonary artery mimicking pulmonary thromboembolic disease. Heart Lung Circ 2006;15:62–3.
[3] Farooki ZQ, Chang CH, Jackson WL, Clapp SK, Hakimi M, Arciniegas E et al. Primary pulmonary artery sarcoma in two children. Pediatr Cardiol 1988;9:243–51.
[4] Gan HL, Zhang JQ, Zhou QW, Xiao W, Gao YM, Liu S et al. Surgical treatment of pulmonary artery sarcoma. J Thorac Cardiovasc Surg 2011;142:1469–72.
[5] Kim HK, Choi YS, Kim K, Shim YM, Sung K, Lee YT et al. Surgical treatment for pulmonary artery sarcoma. Eur J Cardiothorac Surg 2008;33:712–6.
[6] Mayer E, Kriegsmann J, Gaumann A, Kauczor HU, Dahm M, Hake U et al. Surgical treatment of pulmonary artery sarcoma. J Thorac Cardiovasc Surg 2001;121:77–82.
[7] Parish JM, Rosenow EC 3rd, Swensen SJ, Crotty TB. Pulmonary artery sarcoma. Clinical features. Chest 1996;110:1480–8.
[8] Anderson MB, Kriett JM, Kapelanski DP, Tarazi R, Jamieson SW. Primary pulmonary artery sarcoma: a report of six cases. Ann Thorac Surg 1995;59:1487–90.
[9] Tavora F, Miettinen M, Fanburg-Smith J, Franks TJ, Burke A. Pulmonary artery sarcoma: a histologic and follow-up study with emphasis on a subset of low-grade myofibroblastic sarcomas with a good long-term follow-up. Am J Surg Pathol 2008;32:1751–61.
[10] Huo L, Moran CA, Fuller GN, Gladish G, Suster S. Pulmonary artery sarcoma: a clinicopathologic and immunohistochemical study of 12 cases. Am J Clin Pathol 2006;125:419–24.
[11] Dartevelle P, Fadel E, Chapelier A, Macchiarini P, Cerrina J, Parquin F et al. Angioscopic video-assisted pulmonary endarterectomy for post-embolic pulmonary hypertension. Eur J Cardiothorac Surg 1999;16:38–43.
[12] Mayer F, Aebert H, Rudert M, Konigsrainer A, Horger M, Kanz L et al. Primary malignant sarcomas of the heart and great vessels in adult patients – a single-center experience. Oncologist 2007;12:1134–42.
[13] Kruger I, Borowski A, Horst M, de Vivie ER, Theissen P, Gross-Fengels W. Symptoms, diagnosis, and therapy of primary sarcomas of the pulmonary artery. Thorac Cardiovasc Surg 1990;38:91–5.
[14] Thurer RL, Thorsen A, Parker JA, Karp DD. FDG imaging of a pulmonary artery sarcoma. Ann Thorac Surg 2000;70:1414–5.
[15] Ito K, Kubota K, Morooka M, Shida Y, Hasuo K, Endo H et al. Diagnostic usefulness of 18F-FDG PET/CT in the differentiation of pulmonary artery sarcoma and pulmonary embolism. Ann Nucl Med 2009;23:671–6.
[16] Fletcher CD. The evolving classification of soft tissue tumours: an update based on the new WHO classification. Histopathology 2006;48:3–12.

[17] Bleisch VR, Kraus FT. Polypoid sarcoma of the pulmonary trunk: analysis of the literature and report of a case with leptomeric organelles and ultrastructural features of rhabdomyosarcoma. Cancer 1980;46:314–24.

[18] Redmond ML, Shepard JW Jr, Gaffey TA, Payne WS. Primary pulmonary artery sarcoma. A method of resection. Chest 1990;98:752–3.

[19] Blackmon SH, Rice DC, Correa AM, Mehran R, Putnam JB, Smythe WR et al. Management of primary pulmonary artery sarcomas. Ann Thorac Surg 2009;87:977–84.

[20] Jacques JE, Barclay R. The solid sarcomatous pulmonary artery. Br J Dis Chest 1960;54:217–20.

[21] Britton PD. Primary pulmonary artery sarcoma—a report of two cases, with special emphasis on the diagnostic problems. Clin Radiol 1990;41:92–4.

[22] Chhaya NC, Goodwin AT, Jenkins DP, Pepke-Zaba J, Dunning JJ. Surgical treatment of pulmonary artery sarcoma. J Thorac Cardiovasc Surg 2006; 131:1410–1.

[23] Fadel E, Mercier O, Mussot S, Leroy-Ladurie F, Cerrina J, Chapelier A et al. Long-term outcome of double-lung and heart-lung transplantation for pulmonary hypertension: a comparative retrospective study of 219 patients. Eur J Cardiothorac Surg 2010;38:277–84.

[24] Wang HY, Ng B, Blumberg D, Port JL, Hochwald SN, Burt ME. Pulmonary artery perfusion of doxorubicin with blood flow occlusion: pharmaco-kinetics and treatment in a metastatic sarcoma model. Ann Thorac Surg 1995;60:1390–4.

APPENDIX. CONFERENCE DISCUSSION

Dr P. Ciriaco (Milan, Italy): I understand that preoperative diagnosis is an important issue in pulmonary artery sarcoma. So my first question deals with the preoperative work-up. We have found that endobronchial ultrasound is a very useful tool for TBNA, especially to locate pulmonary vessels, and specifically the pulmonary artery. Do you think that this procedure could have a role in the differential diagnosis between pulmonary artery sarcoma and thromboembolic disease?

My second question deals with fibrosis that can be induced by chemotherapy in patients who had neoadjuvant chemotherapy. Did you find any technical differences in patients who underwent neoadjuvant chemotherapy?

Dr Mussot: First, I don't think that EBUS or another ultrasonography technique for adults could be of very much help, but of course if you see an invasion outside of the artery, it is a good clue to imagine it is not CTEPH. Of course, you shouldn't do a biopsy. We had a patient referred after a mediastinoscopy who had proven sarcoma because in fact it was the artery that had been biopsied. EBUS is a new technique we haven't used up to now, but we'll try it in the future.

Concerning neoadjuvant chemotherapy, we haven't noticed any difference in the difficulty of the surgery. It's always a difficult surgery, and this adds no extra major difficulty.

EDITORIAL COMMENT

Pulmonary artery sarcoma

Stuart W. Jamieson

Department of Cardiovascular and Thoracic Surgery, University of California, San Diego, CA, USA

Corresponding author. Department of Cardiovascular and Thoracic Surgery, University of California, San Diego, CA, USA. Tel: +1-858-6577777; fax: +1-858-6575058; e-mail: sjamieson@ucsd.edu (S.W. Jamieson).

Angiosarcomas carry a poor prognosis, and those of the pulmonary artery are no exception. Pulmonary artery sarcomas generally derive from the endothelial cells of the pulmonary artery, and tend to spread within the pulmonary vasculature. Rarely, the pulmonary parenchyma itself is invaded (usually only in the later stages), and, unlike angiosarcomas elsewhere, pulmonary artery sarcomas do not have a high rate of lymph node and systemic metastases. This is perhaps because of the particular anatomy of the lungs—the pulmonary artery being a low-pressure system carrying venous blood and the pulmonary parenchyma having a dual blood supply (the bronchial arteries).

Pulmonary artery sarcomas generally remain asymptomatic until a pulmonary vascular obstruction occurs, and, unless routine screening tests such as X-rays show an abnormality, it is generally the patient presenting with pulmonary hypertension that signals the presence of the intravascular tumour.

Treatment is rarely curative. Since the tumour arises from the endothelium, surgical resection is by endarterectomy and concentrates on restoring the blood flow to the affected areas of the lung to relieve pulmonary hypertension and to restore oxygenation. To date, neither chemotherapy nor radiotherapy has provided significant palliation. A surgical cure of this bad malignancy occurs therefore largely by chance, in a very unusual case when an early diagnosis of unilateral disease allows a pneumonectomy, since pulmonary endarterectomy rarely removes all microscopic cells.

In this paper by Mussot et al. [1], 31 patients underwent operations for pulmonary artery sarcomas over a 14-year period by a surgical team experienced in pulmonary endarterectomy and lung transplantation. Such a concentration of cases of this rare disease is unusual, and results from their referral base in patients with thromboembolic disease of the lungs. Apart from the autopsy series, the only others reporting such a series have also had pulmonary endarterectomy programmes; there have for example been previous reports from Mayer's group [2], the group in Cambridge [3] and our group in San Diego [4]. Mayer's report, as mentioned in this paper, contained a surprisingly small number of sarcomas in their otherwise large practice; perhaps this represents a difference