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Single Posterior Approach for *En-Bloc* Resection and Stabilization for Locally Advanced Pancoast Tumors Involving the Spine: Single Centre Experience

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Study Design: Monocentric prospective study.

Purpose: To assess the safety and effectiveness of the posterior approach for resection of advanced Pancoast tumors.

Overview of Literature: In patients with advanced Pancoast tumors invading the spine, most surgical teams consider the combined approach to be necessary for "*en-bloc*" resection to control visceral, vascular, and neurological structures. We report our preliminary experience with a single-stage posterior approach.

Methods: We included all patients who underwent posterior *en-bloc* resection of advanced Pancoast tumors invading the spine in our institution between January 2014 and May 2015. All patients had locally advanced tumors without N2 nodes or distant metastases. All patients, except 1, benefited from induction treatment consisting of a combination of concomitant chemotherapy (cisplatin-VP16) and radiation.

Results: Five patients were included in this study. There were 2 men and 3 women with a mean age of 55 years (range, 46–61 years). The tumor involved 2 adjacent levels in 1 patient, 3 levels in 1 patient, and 4 levels in 3 patients. There were no intraoperative complications. The mean operative time was 9 hours (range, 8–12 hours), and the mean estimated blood loss was 3.2 L (range, 1.5–7 L). No patient had a worsened neurological condition at discharge. Four complications occurred in 4 patients. Three complications required reoperation and none was lethal. The mean follow-up was 15.5 months (range, 9–24 months). Four patients harbored microscopically negative margins (R0 resection) and remained disease free. One patient harbored a microscopically positive margin (R1 resection) and exhibited local recurrence at 8 months following radiation treatment.

Conclusions: The posterior approach was a valuable option that avoided the need for a second-stage operation. Induction chemoradiation is highly suitable for limiting the risk of local recurrence.

Keywords: Pancoast syndrome; Tumor resection; Chemotherapy; Radiation therapy

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Introduction

First introduced by Pancoast [1] in 1924, superior pulmonary sulcus tumors, which are also known as Pancoast tumors, are relatively rare neoplasms accounting for <5% of all non-small-cell lung carcinomas [2]. Most common histological subtypes are squamous cell carcinoma (52%), adenocarcinoma (23%), and large-cell carcinoma (20%); <5% are of small-cell origin [3]. Their management is challenging because it may involve many critical structures, such as the chest wall, subclavian vessels, brachial plexus, and spine [4]. Thus, these tumors have been considered unresectable and their management has remained purely palliative until Chardack and Maccallum [5] reported a cure of Pancoast tumor by performing resection followed by radiation. A few years later, Shaw et al. [6] demonstrated that preoperative radiation therapy (RT) followed by surgical resection offered superior survival and disease control. This strategy was widely used for >40 years. More recently, Rusch et al. [7] reported in a phase II trial that induction chemoradiation followed by surgical resection showed a significantly higher survival rate than did other pre-existing treatment modalities. Indeed, the reported 5-year survival rate was ≤55% for patients who underwent complete resection. With the use of this trimodality therapy, this entity has evolved from a universally fatal disease to one that is treatable with outcomes similar to those of other stage-matched non-small-cell lung cancers. However, involvement of the spine has long been considered to be a contraindication for such strategy, so these patients are not candidates for curative treatment. With the introduction of modern spinal reconstruction techniques, some recently published series have stressed the feasibility and benefit of "*en-bloc*" resection for advanced tumors with spinal involvement and subsequent reconstruction. Except for patients who harbor limited extension to the vertebrae [8] (foramen or transverse process), most surgical teams propose combined approaches [9-13] that are likely to increase the overall morbidity, which is an important concern in these frail cancer patients. Such combined approaches have been considered to control various visceral, vascular, and neurological structures. However, Jain et al. [14] demonstrated the feasibility of *en bloc* resection and stabilization of Pancoast tumors invading the spine by using a single posterior approach in 2 patients. Although this strategy seems attractive, there is a lack of reported experience [14,15]. We report our preliminary experience using a single-stage posterior approach for treatment of advanced Pancoast tumors invading the spine.

Materials and Methods

1. Inclusion criteria

We included all patients who underwent posterior *en bloc* resection of advanced Pancoast tumors invading the spine in our institution between January 2014 and May 2015. All patients managed for Pancoast tumors in our institution underwent thorough physical examinations, including a detailed neurological examination. They underwent contrast-enhanced computed tomography (CT) of the chest (with coronal and sagittal reconstructions), contrast-enhanced magnetic resonance imaging (MRI) of the brachial plexus, position emission tomography (PET), and brain MRI to rule out distant metastasis. Mediastinal lymph node sampling was performed by using endobronchial ultrasonography-guided needle biopsies. Patients with mediastinal node involvement or distant metastasis were treated with chemotherapy and radiation because they were not eligible for surgical resection with curative intent. Subclavian vessel involvement has been ruled out in all patients. Patients in poor general condition or with altered pulmonary function tests were also excluded. All patients gave their informed consent.

2. Treatment planning

Once surgery was selected, the extent of resection and potential need for stabilization were evaluated. Such evaluation was made on the basis of both CT and MRI. CT is useful to measure the osteolysis and to assess the risk of fracture (vertebral body involvement >50%, vertebral body collapse or sagittal misalignment). However, vertebral involvement may be underestimated and require MRI to identify signs of infiltrative bone disease, which appears as hypointensity on T1-weighted images and hyperintensity on T2-weighted images (Fig. 1). Moreover, MRI is crucial for evaluating the extent of foraminal and epidural involvement. Use of both CT and MRI made it possible to assign each tumor to 1 of the 3 tumor types (Fig. 2) [15] to make the appropriate decision concerning the number of vertebrae involved and extent of bony resection needed (partial or complete vertebrectomy). All patients except 1 were selected to undergo current trimodality therapy involving induction treatment consisting of a combination of concomitant chemotherapy (cisplatin-VP16) and radiation. One patient presented with severe mechanical pain that revealed overt instability on CT. In this particular case, surgery was performed without induction therapy to avoid neurological decline. For patients who underwent induction therapy, the staging was renewed prior to surgery to confirm operability.

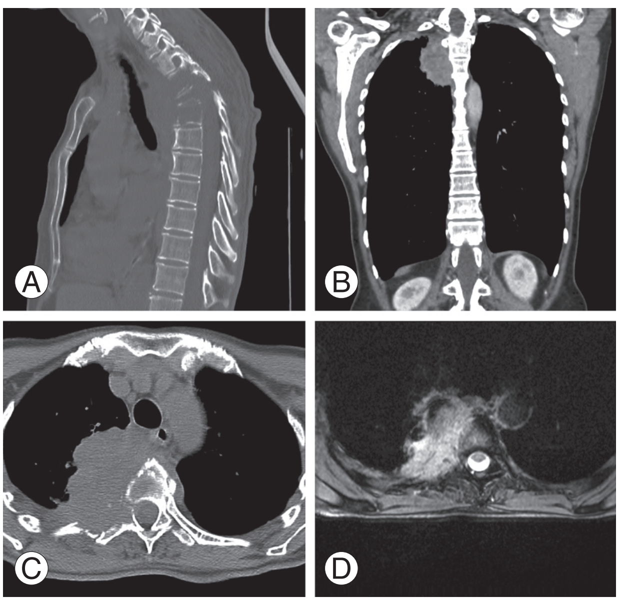

Fig. 1. Preoperative evaluation of a patient with a type-C tumor (patient no. 1). The computed tomography scan in sagittal **(A)**, coronal **(B)**, and axial plan **(C)** reveals the tumor and spinal involvement. The T2-weighted magnetic resonance imaging in axial plan shows a hypersignal for the vertebral bod, which demonstrates bony invasion **(D)**.

3. Surgical procedure

Under general anesthesia, a double-lumen endotracheal tube was inserted under bronchoscopic control. Then, the patient was positioned prone on a Jackson table with both arms extended upward and the head secured in a Mayfield clamp head holder. A posterior midline incision was performed along the spinous processes between C5 and T10. The deep fascia was opened, and the paraspinous muscles were mobilized by using retractors to allow sufficient exposure of the laminae, facets, and transverse processes. At this step, the instrumentation was performed under fluoroscopic control starting by placing the screws in the C5 and C6 lateral mass and the C7 pedicles (Vertex, Medtronic, Minneapolis, MN, USA). At the affected levels, pedicle screws were inserted in the uninvolved side if partial vertebrectomies were planned. Below the affected level, the length of the construct varied from 3 to 5 levels (Table 1) depending on the amount of bone resection required and screw anchorage (Legacy, Medtronic). A piecemeal laminectomy was then performed in front of the affected levels to expose the dura and nerve roots. The nerve roots were clipped and cut on the ipsilateral side when partial vertebrectomies were planned and bilaterally when complete vertebrectomies were needed. When necessary, the T1 nerve root was cut (1 patient) without inducing severe disability (slight hand weakness). However, the C8 nerve root must be respected to avoid postoperative claw-hand deformity and disabling neuropathic pain. When a complete vertebrectomy was planned, wide

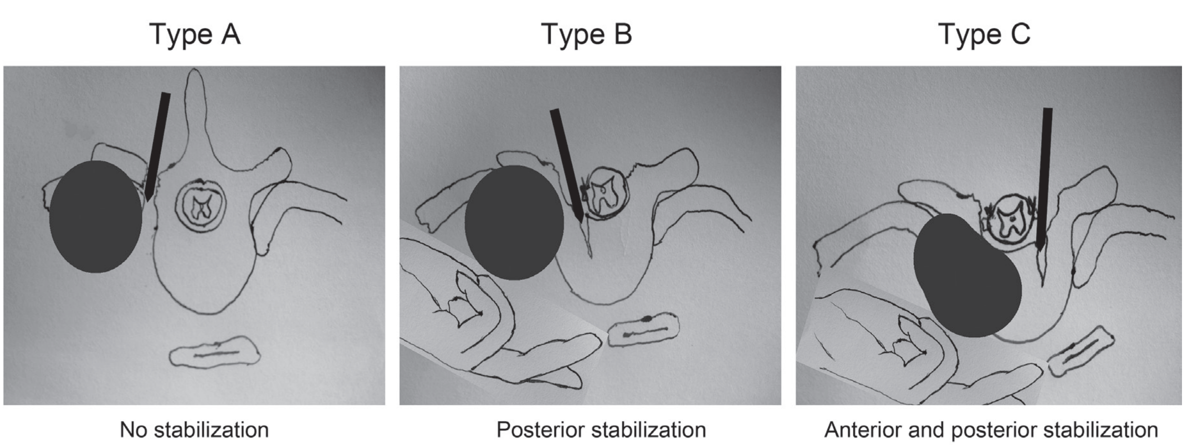

Fig. 2. Artist's illustration showing the amount of spinal resection according to the type of spinal involvement. The arrow represents the osteome, which is placed in the internal part of the ipsilateral pedicle for type-B tumors (after mobilizing the clipped roots) and in the internal part of the contralateral pedicle for type-C tumors.

Table 1. Main demographical data

Patient	Sex	Age (yr)	TNM	Levels	Type[a]	Histology
1	Female	60	T4 N0 M0	T2–T5	C	Squamous cell carcinoma
2	Female	56	T4 N0 M0	T2–T5	B	Adenocarcinoma
3	Male	61	T4 N0 M0	T2–T3	C	Squamous cell carcinoma
4	Male	52	T4 N0 M0	T1–T3	B	Adenocarcinoma
5	Female	46	T4 N0 M0	T2–T5	B	Squamous cell carcinoma

TNM, tumour, node, and metastases.
[a]That refers to the type of spine involvement (Fig. 1).

discectomies were performed at the extremities to allow further mobilization of the affected segment. The stability was ensured on the contralateral side by placing a transitional rod that allowed the transition from a 3.5-mm rod used for the cervical construct and a 5.5-mm rod used for the thoracic construct. Then, the thoracic surgeon performed a posterolateral incision passing below the tip of the scapula, which was connected to the posterior midline incision. The trapezius and rhomboid muscles were sectioned to allow mobilizing the scapula superiorly and laterally to expose the chest wall. Subsequently, the involved ribs were identified. Penetration into the chest cavity was performed as far lateral as possible while allowing for palpation of the tumor and chest cavity to ensure entry at least 4–5 cm lateral and below the tumor. The ribs were divided laterally with shears from below to above, and the neurovascular bundles were ligated as well. At this point, a retractor was positioned beneath the scapula and the top of the inferior rib that permits elevation of the scapula away from the thoracic inlet. This allowed better control of the subclavian vessels (not involved in our cases) and the lower trunk of the brachial plexus. The T1 nerve root was involved and then resected in 1 patient (patient no. 3). With the lung deflated, a window was created laterally to enable the thoracic surgeon to perform the upper lobectomy. The involved lobe was gradually dissected and mobilized by using the Endo GIA stapling device (U.S. Surgical Corp., Norwalk, CT, USA). The hilar portion of the upper lobe and surrounded soft tissues were dissected and freed from the tumor and the spine. The vein, artery, and bronchus to the affected upper lobe were divided and controlled by using the GIA stapling device several time to provide adequate hemostatic control. In 1 patient (patient no. 5), the local extension required performing a complete pneumonectomy that was not initially planned. Using a blunt finger dissection, the thoracic surgeon separated the mediastinal structures (vessels and esophagus) from the anterior part of the vertebral bodies and protected them while the neurosurgeon performed the vertebrectomies by using the osteotomes at all levels. The amount of bony resection depended on the degree of vertebral involvement. All patients had significant involvement that was measured preoperatively by performing both CT and MRI. Such involvement required either partial (type B) or complete (type C) vertebrectomies that respected a safety margin (1–2 cm) to avoid any violation of the tumor. For type-B lesions, the osteotomy was performed just medially to the ipsilateral pedicle, vertically toward the anterior wall (Fig. 2). For type-C lesions, the osteotomy was performed medially to the opposite pedicle. Then, we performed the remaining dissection at the superior part, cutting the scalene muscles and ensuring the absence of adherences with the subclavian vessels and brachial plexus. The tumor was then gradually tilted from down to up, which enabled cutting the anterior longitudinal ligament and control of the segmental vessels that were clipped and cut. After removing the tumor *en bloc*, complete ipsilateral mediastinal lymphadenectomy was performed in all cases (Fig. 3). We completed the construct by placing and locking the second rod as well as 2 cross-connectors. An anterior construct was placed and loaded into compression for patients who underwent complete vertebrectomies (Figs. 4, 5). After ensuring the absence of cerebrospinal fluid (CSF) leak, biological glue was applied systematically on the dura and the roots to enhance the seal. At the end of the procedure, a chest tube was placed following irrigation of the chest cavity. The divided muscles were meticulously reapproximated while ensuring that the scapula entirely covered the chest wall defect to prevent the risk of entrapment of the tip of the scapula into the defect that could generate pain and limit shoulder girdle motion.

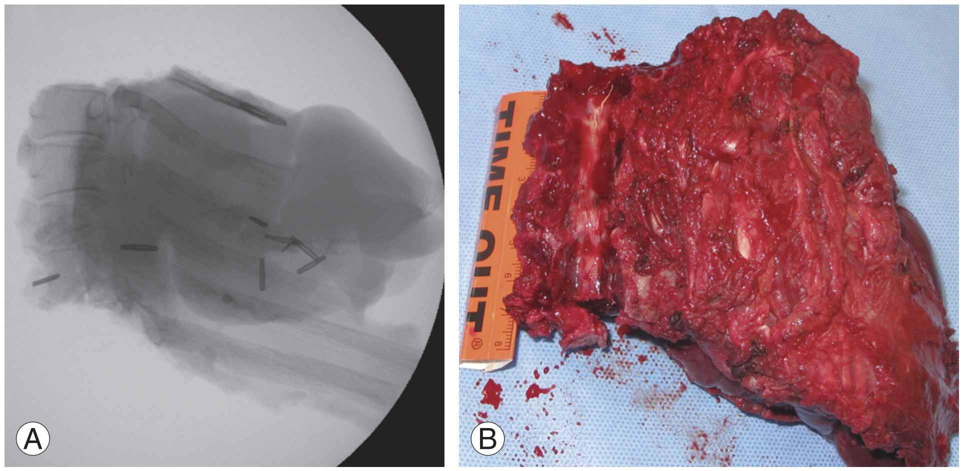

Fig. 3. Specimen and its radiograph **(A, B)** showing the *en bloc* resection of the tumor, chest wall, and the 4 involved vertebrae.

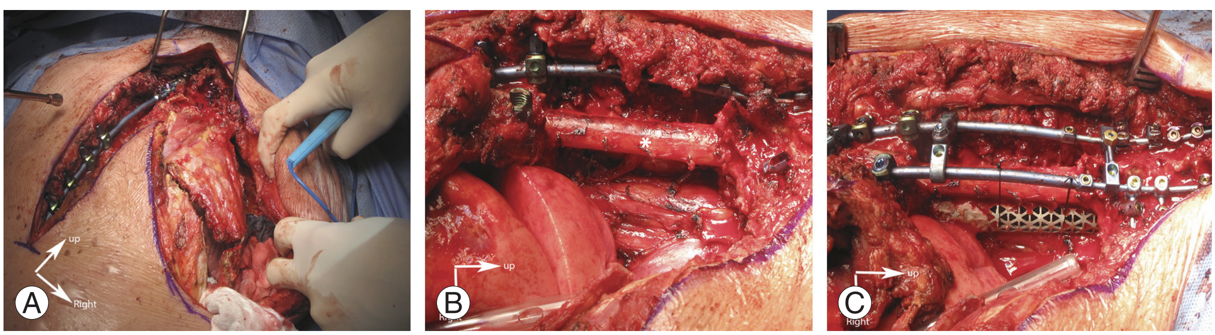

Fig. 4. Different stages of the surgical procedure. After performing the posterior stabilization, the exposure of the chest wall is performed by using a lateral incision **(A)**. The tumor is then resected *en bloc*, taking care to protect the mediastinal structures and the spinal cord **(B)**. Note that the roots have been previously dissected and clipped (*). The anterior construct is then completed by using a pyramesh **(C)**.

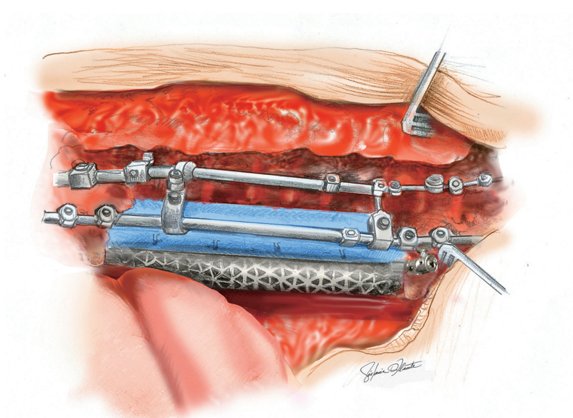

Fig. 5. Artist's illustration of the surgical field after resection of the tumor and spinal stabilization.

Results

1. Population

A total of 5 patients were included in this study (2 men, 3 women; mean age, 55 years; range, 46–61 years). No patient harbored lymph node or systemic metastases on preoperative evaluation. Histological analyses revealed squamous cell carcinoma in 3 patients and adenocarcinoma in 2. On the basis of both CT and MRI, the tumors were classified as type B in 3 patients and type C in 2 patients because all demonstrated significant spinal involvement. The tumor involved 2 adjacent levels in 1 patient, 3 levels in 1 patient, and 4 levels in 3 patients. The main demographic data are summarized in Table 1.

2. Operative parameters

There were no intraoperative complications. The mean operative time was 9 hours (range, 8–12 hours), and the mean estimated blood loss was 3.2 L (range, 1.5–7 L). Blood loss and operative time were both higher in the first patient of our series, for whom 4 levels of complete

Table 2. Main operative parameters

Patient no.	Induction	Spinal resection	Posterior construct	Anterior construct	Margins	EBL (mL)	Operative time (hr)	Complication
1	None	Vertebrectomy T2–T5	C4–T9	Yes	R1	7,000	12	None
2	Chemo+ radiation	Hemivertebrectomy T2–T5	C5–T9	No	R0	1,500	8	Cerebrospinal fluid leak[a]
3	Chemo+ radiation	Vertebrectomy T2–T3	C5–T8	Yes	R0	2,500	8	Chylothorax[a]
4	Chemo+ radiation	Hemivertebrectomy T1–T3	C5–T6	No	R0	2,000	8	Wound infection[a]
5	Chemo+ radiation	Hemivertebrectomy T2–T5	C5–T10	No	R0	3,500	9	Prolonged ICU stay

EBL, estimated blood loss; ICU, intensive care unit.
[a]Complications that required reoperation. For surgical margins, R0 indicates that the resection is complete with microscopic examination of margins showing no tumor cells, and R1 indicates that resection is macroscopically complete but margins shows tumor cells when viewed microscopically.

vertebrectomies were required (Table 2). Note also, that in all cases the osteotomy was the most hemorrhagic stage of surgery. Surgical margins were negative (R0) in 4 patients and positive in 1 patient because the tumor had reached the canal and had a mass effect on the dura.

3. Postoperative course

The mean length of hospital stay was 15.4 days (range, 9–28 days). No patient had a worsened neurological condition at discharge except for expected mild hand weakness related to sacrificing the T1 nerve root in 1 patient (patient no. 4). We reported 4 complications in 4 patients. One case of CSF leakage required reoperation to enhance sealing with sutures and a muscle flap. One patient had a chylothorax that needed revision surgery to ligate the thoracic duct. One patient had a superficial wound infection treated with surgery and antibiotics for 3 weeks with good

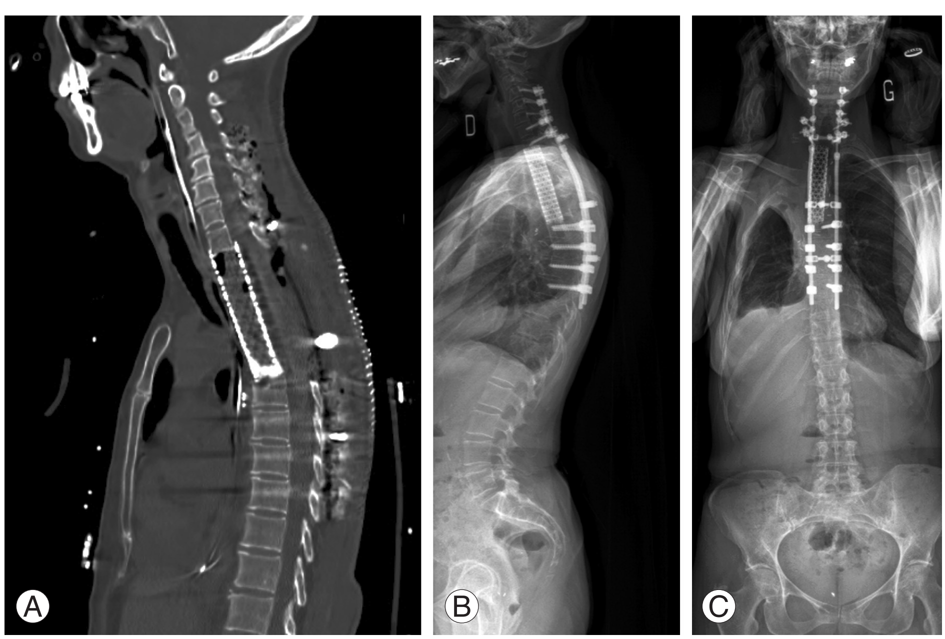

Fig. 6. Postoperative computed tomography scan in sagittal reconstruction showing the final construct **(A)**. Lateral **(B)** and antero-posterior **(C)** standing X-rays performed at 3 months demonstrating the construct and the spinal alignment.

outcome. Finally, the patient for whom surgery had required pneumonectomy had an extended stay in intensive care for respiratory distress, with good final outcome. All patients benefited from postoperative CT that confirmed good positioning of the implants in all cases (Fig. 6). Note that no patient presented hardware failure during the follow-up.

4. Tumor control

The mean follow-up was 15.5 months (range, 9–24 months). As stated previously, the first patient underwent a gross total resection (R1) without prior therapy. Thus, she benefited from adjuvant chemotherapy (combination cisplatin and vinorelbine). Unfortunately, she presented a local recurrence 8 months later treated by local radiation. She died 12 months after surgical resection. The other patients, who benefited from chemoradiotherapy followed by R0 resection, have remained disease-free.

Discussion

1. Tumor staging

Treatment of Pancoast tumors has dramatically evolved over the last decades. This disease, which has long been felt to be incurable, is currently amenable to curative treatment. However, some key prognostic factors have been identified as severely affecting the survival rate. The most important factors are the T status, completeness of resection (R0 vs. R1 or R2), and nodal status [16,17]. Initial careful assessment and appropriate staging are mandatory to select patients for whom curative-intent *en bloc* resection is suitable and to not expose others to excessive and unjustified morbidity. The first step consists of obtaining tissue diagnosis to determine the tumor histology and rule out rare differential diagnosis of such infection.

Because of the peripheral nature of Pancoast tumors, cytological analysis of expectorated sputum and bronchoscopy with transbronchial biopsy have a low diagnostic accuracy [18]. Transthoracic or cervical CT-guided needle biopsy is the most sensitive procedure [19], which has a diagnostic yield >90%. The degree of tumor invasion into the surrounding structures must be finely determined by using both CT and MRI. Although MRI was found to be more accurate in the evaluation of the tumor's relationship to the brachial plexus, subclavian vessels, and vertebrae [20], CT and MRI are complementary and both must be performed systematically. In most institutions, surgical resection is performed by a multidisciplinary team consisting of a thoracic surgeon and a spine surgeon (orthopedic or neurosurgeon).

Although vascular and spinal involvement are no longer considered to be contraindications for surgery, it is important that all members of the relevant specialties can see the patients to make certain that the tumor can be resected with an acceptable morbidity. Evaluation of the mediastinum for lymph node metastases is also a major concern because patients with mediastinal N2 or N3 nodal involvement must be contraindicated for surgery and be treated with radiation and chemotherapy [21]. However, hilar N1 nodal involvement does not preclude surgery, and patients should still be considered for curative treatment. Noninvasive evaluation by CT is limited by substantial false-positive and false-negative results depending on the criteria used to define enlarged lymph node [22]. Although, PET has improved the sensitivity and specificity rates (74% and 85%, respectively), invasive assessment techniques with sampling of suspicious nodes are highly recommended before curative surgery is attempted [23,24]. Current techniques include endobronchial ultrasonography-guided needle biopsy, tranesophageal endoscopic ultrasonography-guided biopsy, or mediastinoscopy [24]. Once the evaluation is performed, patients for whom the tumor is considered resectable and who harbor neither distant metastases nor N2–N3 nodes can be offered curative treatment.

2. Trimodality therapy

The advantage of performing preoperative RT was first promoted by Shaw et al. [6] in 1961. The potential benefits include a decrease in tumor size to improve resectability by shrinking the tumor, reduction in viable cells to limit the risk of seeding cells during resection, and blockage of the lymphatics to limit the risk of seeding. Despite the lack of randomized studies, this treatment was generalized because many series have reported better local control and survival rates (30% at 5 years), especially in patients who underwent complete resection and whose specimens revealed rare viable cells after irradiation [25]. The rationale of adding concurrent chemotherapy to preoperative RT was to improve resection rates and to treat occult systemic disease to limit the risk of distant relapse. Rusch et al. [7]

reported the results of a phase 2 trial of chemoradiation followed by surgical resection. Patients received 2 cycles of cisplatin and VP16 concurrent with 45 Gy of radiation. They reported a complete resection rate of 92% and a 5-year survival rate of 44% for all patients and 54% after complete resection, which is superior to historical controls of radiation plus surgery. Although, the trimodality therapy has become a “standard of care” in patients with Pancoast tumors, many drawbacks must be noted. This preoperative regimen can be difficult to tolerate, especially in debilitated patients. For example, of the 110 patients included in the trial of Rusch et al. [7], only 88 were operated on. Preoperative radiation has the disadvantage of creating a “fibrous scar” around the tumor, which makes margins less apparent and surgical dissection more difficult. In addition, preoperative RT is likely to increase the risk of complications, such as infection, wound-healing problems, CSF leakage, and pseudarthrosis. However, it seems that the benefits of this treatment strategy outweigh its potential risks.

3. Relevance for Pancoast tumors with spinal involvement

Note that despite its wide use, there has been no phase 1 study supporting this treatment strategy. This is particularly true in the subset of patients with Pancoast tumors invading the spine for whom the usefulness of surgery has not been well documented. Indeed, the majority of published reports are case reports or limited retrospective case series. In most series reporting surgical treatment of advanced Pancoast tumors involving the spine, the 5-year survival rates range between 14% and 61%. The use of various surgical techniques, inconstant use of induction therapies, and variable inclusion criteria explain these important differences among series [8-14,26,27].

In 2013, Collaud et al. [11] reported a large series of 48 consecutive patients who had undergone *en bloc* resection of non-small-cell lung cancer invading the pulmonary sulcus and spine. Patients benefited from concurrent chemoradiation preoperatively, in accordance with the current trimodality therapy. Total vertebrectomy was required in 10 patients, hemivertebrectomy in 31 patients, and partial vertebrectomy in 7 patients. Complete resection (R0) was achieved in 42 patients (88%). The overall 5-year survival rate was 61%, with complete resection and response to induction being important prognostic factors. Thus, aggressive surgical treatment enabling *en bloc* resection of Pancoast tumors invading the spine should be recommended in selected patients but when preceded by induction chemoradiation, as for other superior pulmonary sulcus tumors.

4. Surgical approaches

As stated previously, surgery aims to achieve resection of the upper lobe, involved ribs, stellate ganglion, lower trunk of the brachial plexus, invaded part of the vertebrae, and any other involved structures in an *en bloc* fashion while ensuring spinal stability. Some teams have developed extensive surgical techniques and advocating that as for most locally advanced malignant primary tumors, radical surgical resection remains the only chance of cure. Currently, the choice of approach depends on many criteria, including the location of the tumor, extension into the vertebrae, subsequent need for spinal stabilization, and surgical team experience.

In type-A tumors (Fig. 1), the vertebral extension is limited and spinal stabilization is not needed. Then, resection can be achieved via a single posterolateral thoracotomy, the so-called Shaw-Paulson approach. This allows performing the whole dissection through an approach familiar to thoracic surgeons, a limited osteotomy being performed by using osteotomes at the end of the procedure. Anterior approaches could be used alternatively. Popularized by Dartevelle et al. [28], the anterior trans-cervical approach provides adequate access to the brachial plexus and the subclavian vessels, which makes their handling and dissection safer. An L-shaped incision starting along the sternocleidomastoid muscle is extended horizontally and below the clavicle. After muscle detachment, the medial half of the clavicle is removed, which completes access to the thoracic inlet. Many modifications have been described, with the transmanubrial approach reported by Grunenwald and Spaggiari [29] being the most popular. It allows excellent access to the subclavicular region while avoiding the functional and cosmetic complications of clavicle resection. These approaches allow the surgeon to perform partial vertebrectomy and to access the foramen if needed.

In locally advanced tumors (type B or C), most described techniques involve 2 or 3 stages when *en bloc* resection is suited because spinal stabilization is required. Indeed, York et al. [15] described a single-stage procedure for “gross total resection” and stabilization of advanced

Pancoast tumors with spinal involvement in a lateral positioning. However, the vertebrectomies were performed by using a high-speed drill, which does not respect the principles of oncological surgery and has a higher risk of local recurrence and tumor seeding. Moreover, performing an extended dorsal stabilization while maintaining a proper alignment in a lateral positioning is technically very demanding. Despite the use of hooks and wires, the authors reported that one third of patients presented early hardware failure and required cervicothoracic fixation. Currently, most surgical teams agree that the posterior approach represents the first surgical stage. This approach allows the spine surgeon to perform a solid posterior construct to control the spinal canal, ligate the roots if needed, and perform the osteotomy with more security with regard to neural elements. Afterwards, the tumor was classically approached and resected through an anterior approach or a posterolateral thoracotomy, which also permitted placement of an anterior construct if a complete vertebrectomy was required. No one questioned the need to perform a second-stage procedure until Jain et al. [14] reported the outcomes of 2 patients with Pancoast tumors involving the spine who underwent *en-bloc* resection using a single-stage posterior approach. Since the initial description, our series is the first that confirms the feasibility of this procedure that eliminates the need for a second-stage operation. An advantage of this approach is that it offers a wide exposure of the tumor and the adjacent neurovascular and visceral structures. Indeed, all patients who underwent the trimodality therapy experienced complete resection with clear margins (R0). Complete resection was not achieved in 1 patient who presented an important extension into the canal. It is unlikely that another approach would have led to a better resection. However, the indication for curative surgery was questionable prior to any induction therapy. A second option would have been to extensively resect the underlying dura as done for other primary malignant tumors of the spine [30].

5. Complications and limits

En bloc resection of Pancoast tumors with spinal extension is associated with an important complication rate that ranges from 28% to 52% regardless of the approaches used [9-15,26,27]. Among these complications, pulmonary issues from atelectasis, pneumonia, edema, or embolism are most frequently reported. Infections are also a major problem. Indeed, these patients present numerous risk factors, such as the preoperative chemoradiation, the scar located on the radiation field, and the prolonged operative time. As in our series, prompt debridement and antibiotic therapy are mandatory to avoid thoracic, neurological, or osseous contamination that can severely affect prognosis. With prompt and appropriate treatment, patients often experience favorable outcome [7,9]. In our series, one patient experienced CSF fistula. This complication occurred despite the absence of leakage visualized during the initial surgery neither on the exposed dura nor on the clipped roots. Because of the negative intrathoracic pressure that favors and maintains the leak, such complications should be suspected and treated quickly. In our experience, no intraoperative complication occurred. No patient had worsened neurological condition postoperatively in our series. Indeed, some authors recommend performing preoperative angiography when multiple adjacent roots are expected to be cut [9,10]. Although none of our patients experienced spinal cord infarction, the legitimacy of performing initial angiography can be debated. Moreover, preoperative embolization could be an option because the osteotomy was the most hemorrhagic step in all cases. Despite the limited follow-up, no patient developed hardware failure or pseudarthrosis. Disabling mechanical complications have been frequently reported; these must be prevented by favoring long constructs in all cases and circumferential reconstructions when needed. The posterior midline approach, which is familiar to spine surgeons, and the wide access to the anterior column are particularly suitable.

However, this procedure has certain limitations. The thoracic surgeon must perform the upper lobectomy and chest wall resection in a ventral position that may be more challenging and require a trained surgical team with perfect knowledge of the relevant anatomy. Moreover, as also reported by Jain et al. [14], we have experienced long operative times that require endurance. It is likely that increased experience will reduce operative times. Finally, the small number of included patients to date and the limited follow-up have prevented determining if this strategy is likely to improve the functional prognosis and overall survival.

Conclusions

The posterior approach appears to be a valuable option to achieve *en-bloc* resection of advanced Pancoast tumors with spinal involvement. The need for a second-stage operation was avoided, and vascular, visceral, or neurological complications were not encountered in this case series. Induction chemoradiation is highly suitable to limit the risk of local recurrence.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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