Experience with the autologous pulmonary vein for pulmonary arterioplasty

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Abstract

Objective: Lobectomy with pulmonary artery resection and reconstruction is seldom performed in order to avoid pneumonectomy in selected cases. The aim of this study is to determine how safe and effective the graft reconstruction of the pulmonary artery is, using autologous tissue taken from the pulmonary vein. Methods: Eight patients with diagnosed non-small-cell lung cancer were treated by lobectomy with pulmonary artery reconstruction with curative intent. All patients could have tolerated pneumonectomy. Patch or conduit angioplasty was performed by using a tailored graft, harvested from the autologous pulmonary vein of the resected lobe. Patients were followed up and the clinical records were analyzed retrospectively. Long-term patency of the reconstructed pulmonary artery was investigated by computed tomographic pulmonary angiogram. Results: No procedure-related complications and no perioperative mortality were observed. No blood transfusion was required. Follow-up varied from 10 to 64 months. No local recurrences were found next to the angioplasty. Ideal long-term patency of the pulmonary artery was demonstrated in all cases. Two patients are alive with evidence of extrathoracic metastatic disease and four patients are apparently healthy. Two patients died of progressive disease. Conclusions: The use of pulmonary vein tissue as a graft to repair the pulmonary artery is feasible, reproducible, and seems to be oncologically correct. Pulmonary vein tissue can be easily harvested during surgery and offers a high-quality vascular tissue for pulmonary angioplasty.

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Keywords: Pulmonary artery resection and reconstruction; Lung cancer; Surgery; Lobectomy

1. Introduction

A lobectomy with angioplasty is performed as an alternative to pneumonectomy in selected patients, primarily those requiring treatment of left upper lobe cancer. The feasibility and the oncologic value of a lobectomy with pulmonary artery (PA) resection and reconstruction have been validated by several studies [1—8], but, to date, the techniques involved have been not conclusively standardized. Specifically, the criteria to be used in choosing the PA reconstruction technique and the selection of the ideal prosthetic material are uncertain. Prosthetic reconstruction of the PA has been favorably performed by patch repair or, rarely, by conduit techniques through the use of different materials. Among these, the autologous pericardium was by far the most widely used material, although it is not ideal for PA repair because it is not sufficiently stable after harvesting. Other materials, such as autologous azygos vein, bovine pericardium, and synthetic grafts [2,6—8—10], have been occasionally experimented, but have not found current application for a variety of reasons.

We have recently found the pulmonary vein (PV) to be a good option for PA reconstruction and report herein our preliminary experiences.

2. Patients and methods

As of 2005, we started to repair the PA using the tissue of the resected left superior PV and the technique was employed in eight patients, who underwent left upper lobectomy for non-small-cell lung cancer. Clinical records were retrospectively analyzed and further data were collected from patient surveys and the referring oncologist. Indication for surgery, clinical staging work-up, preoperative cardiopulmonary function tests, possible induction therapy, technical details of the reconstructive vascular procedure, and the postoperative course were evaluated.

All patients were scheduled for pulmonary lobectomy and possibly pneumonectomy after a standard preoperative work-up, including complete blood count, biochemical blood analyses, and blood gas analyses. Cardiovascular and respiratory functions were inspected by electrocardiography,
Doppler echocardiography, and pulmonary tests. The clinical stage was assessed through chest X-ray, total body contrast computed tomography (CT), videobronchoscopy, and fluorodeoxyglucose positron emission tomography (FDG-PET) scan. When the latter showed a suspected N2 disease, transbronchial needle aspiration (TBNA) biopsy was performed. In one patient, a bone scan was performed to clarify an FDG-PET finding of uncertain significance. Histological diagnosis was achieved preoperatively through videobronchoscopy or trans-thoracic needle biopsy. In the case of N2 disease, cisplatinum-based induction chemotherapy was administered; patients were then restaged at the end of medical treatment. The conservative procedure was performed as a deliberate choice to avoid pneumonectomy, which theoretically would have been tolerated by all the patients in our series. Systematic node dissection was always associated. Postoperative thromboembolic prophylaxis included subcutaneous Enoxaparin 4000 units once daily for a period of 21 days. No long-term platelet antiaggregant therapy was suggested. Surgical pathology was conducted using morphologic and immunohistochemical techniques and evaluated according to the 2009 International staging system for the study of lung cancer. All patients were followed up (mean 25.125 months, range 12–66).

The vascular graft patency was assessed 3–6 months after surgery by contrast CT with multiplanar reconstruction. All patients were then followed up by an oncologist who scheduled a chest X-ray after 1 month and a contrast CT every 6 months for the following 30 months. The latter was then scheduled every 12 months if the patient was formerly negative for cancer relapse. Between CT series, an F-18 FDG-PET scan was examined yearly.

Data were managed using Microsoft Excel and its statistical network (Microsoft Corp, Redmond, WA, USA). The study was conducted with the patients’ consent and in accordance with bioethical principles in medical research.

2.1. Technique

The procedures were performed under general anesthesia with double-lumen tube placement; the chest cavity was entered through a standard postero-lateral thoracotomy. The PA angioplasty had been scheduled prior to thoracotomy in six cases. Indication for the vascular reconstructive procedure was direct PA infiltration by the tumor in five cases and PA involvement by metastatic nodes in three. Five left upper lobectomies (LUL), one bronchial sleeve LUL, and two LUL extended to the superior segment of the left lower lobe were performed. Mediastinal node dissection was always carried out prior to angioplasty. Frozen section examination disclosed R0 margin at vascular and bronchial levels in all patients.

After thoracotomy closure, pain was controlled by means of continuous endovenous morphine, paracetamol, and paravertebral levobupivacain.

2.2. PV graft harvesting and angioplasty

If macroscopically free of cancer involvement and sufficiently distant from the tumor, the superior PV was exposed from the intrapericardial tract to the peripheral main branches by a careful preliminary subadventitial dissection. The PV was then sutured intrapericardially using a vascular linear stapler as close as possible to the left atrium and ligated distally (Fig. 1). All the tissue included between the intrapericardial stump and the peripheral branches was collected and dipped in 0.9% saline solution before shaping. Proximal control of the main PA was achieved, intra- or extrapericardially, using a Satinsky clamp; either a Bulldog clamp or a tourniquet was placed distally to the neoplastic vascular infiltration. Once the lobe had been removed, a fine measurement of the vascular defect was conducted. PA always offered sufficient tissue for patch repair even in the case of large PA gaps (20 mm × 20 mm).

Patch reconstruction was employed in PA defects larger than a quarter of the anterior wall when the tangential resection with direct suture would have left unsatisfactory functional anatomy of the vessel; the patch was tailored with the PV tissue, previously harvested, based on the PA gap and put in place using two steps of semicircular 5/0 nonabsorbable monofilament running sutures.

After complete vascular sleeve resection, a conduit interposition was performed on one patient with long PA involvement, extending from the first branch to the branch in the superior segment of the left lower lobe. A 15-mm PV conduit interposition was deemed suitable for reconstruction because tension between the stumps was anticipated. Proximal anastomosis between the PA and the conduit was carried out first.

In all patients, at the end of the angioplasty, the proximal clamp was removed just before tying the last suture in order to eliminate intravascular air. Sodium heparin was intravenously administered (700 UI/10 kg) and neutralized immediately after the vascular procedure. No protective flap was employed. No systemic or topical hemostatic agents were used.

3. Results

Three patients were female and five were male. The mean age was 66 years ranging from 49 to 80 years (median age 64 ± 10.2 years). Comorbidities (single or multiple) were present in 5/8 cases: 3/8 chronic obstructive pulmonary disease, 1/8 coronary artery disease, 1/8 sideropenic anemia, 1/8 epilepsy, and 1/8 cerebrovascular disease.
The disease was asymptomatic in 5/8 cases and began with cough, dyspnea, and fever in one patient, respectively. No limiting major cardiopulmonary impairment was detected during the work-up. Preoperative spirometry showed a forced expiratory volume in one second of at least $>60\%$ in all patients. Induction chemotherapy was performed in 2/8 cases with N2 disease; after restaging, which showed stable disease, both patients were scheduled for resection after a multidisciplinary team discussion. PA reconstruction was carried out using 1/8 PV conduit interposition and 7/8 PV patch placement. No blood transfusion was required. Analysis disclosed 3/8 adenocarcinomas, 4/8 squamous cell carcinomas, and 1/8 large-cell neuroendocrine carcinoma. The T parameter ranged from 12 to 60 mm (mean 38.875 mm and median 39.5 mm) and it was identified as T1a in 1/8 cases, T1b in 1/8 cases, T2a in 4/8 cases, and T2b in 2/8 cases. All these data are reported in Table 1. No N bulky mediastinal disease appeared at the time of surgery, and final pN0 was found in 2/8 cases, pN1 in 4/8 cases, and pN2 in 2/8 cases. Pathological staging analysis labeled 1/8 stage IB, 4/8 stage IIA, 1/8 stage IIB, and 2/8 stage IIIA. The PA wall was directly infiltrated by the tumor in 2/8 cases, and by metastatic lymph nodes in 5/8 cases; in one patient the PA wall resulted pathologically uninvolved. No perioperative mortality was recorded. Two postoperative complications occurred: left vocal cord paralysis and transient atrial fibrillation. The PA clamp time was 15 $\pm$ 4 min for the patch placement. The hospital stay lasted a mean of 8.8 days ranging from 8 to 10 (median 8.5 $\pm$ 1 day). Three patients underwent adjuvant chemotherapy according to stage-recommended therapy guidelines and the oncologists’ decision. No patients received postoperative radiotherapy.

No patient was lost during follow-up. At the time of the last clinical evaluation (February 2011), 2/8 patients were dead, respectively, at 21 and 29 months due to disease progression, 2/8 patients were alive with evidence of extrathoracic disease (cerebral metastasis or bone metastasis), respectively, at 12 and 22 months and were treated by chemoradiotherapy. Four patients are alive at 12, 24, 31, and 66 months without evidence of disease. We found only one local recurrence in the anterior chest wall, away from the reconstructed PA: the patient had previously undergone a coronary artery bypass graft with the left internal thoracic artery. In this case, the adhesions made it difficult to separate the apex of the upper lobe and the graft, without jeopardizing the myocardial revascularization. All follow-up data are presented in Table 2.

Postoperative contrast chest CT scans did not disclose leaks or local recurrences at the site of the reconstructed PA. A normal PA lumen was demonstrated in all patients who underwent patch reconstruction, without any radiologically identifiable sign of the angioplasty procedure. In the patient treated by conduit angioplasty, a moderate stenosis was detected at the level of the proximal anastomosis of the conduit, mostly related to the caliber mismatch between the PV graft and the main PA (Fig. 2). Such stenosis did not alter the blood flow as demonstrated by postoperative quantitative lung perfusion scintigraphy with Tc-99 m macroaggregated albumin, which showed no impairment of pulmonary perfusion.

### Table 1. Pathological data and staging.

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### Table 2. Follow up records.

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**4. Discussion**

After initial reserve about the oncologic value of lobectomy with PA resection and reconstruction [11], these procedures have been accepted by the thoracic surgery community as a valuable option to avoid pneumonectomy in selected cases. Various techniques have been improved for PA reconstruction. PA primary repair is suitable only for small

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Fig. 2. Vitrea® system CT angiogram shows pulmonary angioplasty with PV conduit interposition: moderate anastomotic stenosis (arrow) without blood flow impairment.
defects (less than a quarter of the anterior wall) due to the resulting stenosis. Patch reconstruction is an effective method in the case of moderately extended defects. Polytetrafluoroetilen (PTFE Teflon®, W.L. Gore & Associates, Inc.) has been occasionally reported for PA angioplasty [5], but not commonly performed because it is deemed to result in a high risk of thrombosis. Autologous tissue is currently the favorite choice. The employment of the autologousazygos vein is limited, since in most cases pulmonary angioplasties are indicated for left lung tumors. The great saphenous graft has also been tested [4], but rarely employed because the procedure appears to be tricky in view of an additional operative field and the different operative position required. The techniques of PA reconstruction with autologous pericardium have been very well described by Rendina and colleagues [2]. Although widely used, the autologous pericardium’s stability is unsatisfactory as it may shrink or curl with consequential technical problems. The most experienced authors in PA patching with pericardium have reported possible significant postoperative bleeding, originating from the twisting of the graft [3]. These authors have proposed stiffening the pericardium using a glutaraldehyde solution to avoid graft deformation [12], at the price of possible tissue damage and calcification [13].

Even though our experience is preliminary, we consider the PV, harvested from the left upper lobe, an excellent source of autologous tissue for PA reconstruction. The PV histo-physical properties are superlative: the PV wall is a distinctive vascular tissue with favorable thickness, resistance, and solid consistency. The PV wall comprises a thin endothelium, a thick outer fibrous adventitia, and a smooth muscle media layer which microscopically overlaps with the atrial myocardium [14]. PV tissue accepts tension, suturing, and manipulation, does not begin to curl and shrink, possesses an ideal vascular endothelium, and does not require additional surgical procedures for harvesting, beyond intrapericardial dissection.

Our experience with such techniques is limited to the use of the left superior PV but, theoretically, both inferior PVs are suitable for patch angioplasty after lower lobectomies. Conversely, the technique of PA reconstruction with the use of the vein of the resected lobe is not applicable after a right middle or right upper lobectomy, for obvious anatomical reasons, but on the right side the use of the azygos vein is a good option.

When PA angioplasty is planned, the PV of the lobe to resect, if uninvolved, should be considered as a source of tissue. The use of such a technique is relatively influenced by anatomical variability. The left superior PV, intrapericar-dially exposed and harvested by the described technique, supplies sufficient tissue for a patch reconstruction, even in the case of nonideal anatomy. In our experience, the longitudinal slit of the PV specimen’s wall provides sufficient surface for patching defects up to half of the anterior wall. In any case, if the graft is smaller than the PA defect, a limited mismatch does not entail technical and hemodynamic problems: in fact, a mild ensuing stenosis of the reconstructed PA is well tolerated considering the necessary perfusion of the residual lobe.

A successful PA repair by a PV conduit has been recently described by Cerezo and colleagues [15]. Several considera-

ations must be made regarding the use of the conduit graft placement technique. The procedure is very rarely needed after a complete vascular sleeve resection. Subadventitial dissection of the PA and hilar release, as adopted in carinal surgery, generally support and allow direct arterial anastomosis. When, in exceptional circumstances, a conduit is required, the PV graft is a good option, but it can be used only in the case where there is a long PV and limited caliber mismatch between PA stumps and the graft. Such favorable anatomic conditions occur quite infrequently. When suitable anatomy is encountered, the PV shows significant advantages over the autologous pericardium in conduit angioplasty: the channel shaping technique is simpler, quicker, and safer; and the PV tissue is more appropriate. Furthermore, a prosthetic repair of the pericardial gap may be required for very large harvesting. In one of our patients, after an extensive vascular sleeve resection, we successfully interposed a 1.5-cm-long PV graft between the intrapericardial PA stump and the distal PA to the left lower lobe. The caliber discrepancy between the PA and the conduit had no hemodynamic consequences and long-term graft patency was demonstrated. The length of the conduit is not critical since a 1—2-cm graft is adequate: a longer conduit is undesirable, due to the risk of kinking, turbulence, and possible thrombosis [3].

The main concern regarding the use of PV angioplasty is related to the oncologic reliability of such a procedure. We think that the technique is oncologically adequate, provided indications and techniques are correct. In our limited experience, we found neither local recurrences at the level of the PV-graft angioplasty nor other oncological or technical drawbacks. In lobectomies with angioplasty, the width of the arterial resection margins is unavoidably very limited and, for such reason, a frozen section proof of the arterial wall is necessary; frozen section analysis of PV resection margins is not contemplated in any lobectomy, if the vein is grossly free of tumor. As most of pulmonary angioplasties are performed for left upper lobe tumors involving the interlobar PA, the superior PV is usually adequately distant from the cancer. In locally advanced disease involving the anterior hilum, a conservative procedure, alternative to a pneumonectomy, is rarely performed and the described method is not indicated.

In conclusion:

1. the PV supplies superlative vascular tissue for angioplasty;
2. harvesting is very simple and quick;
3. no additional surgical trauma is required;
4. the procedure is safe and appears to be oncologically adequate.

For said reasons, even though further experience is needed, we believe that the use of the uninvolved PV is to be considered a useful method for PA repair after left upper lobectomy.

References


