Lung function and perfusion after bronchial and pulmonary arterial sleeve resection

Abstract  Between January 1985 and December 1991, six patients underwent arterial and bronchial sleeve resections of the left upper lobe. Preoperative and postoperative spirometry, preoperative split pulmonary radionuclide ventilation/perfusion (V/Q) scans and postoperative bronchoscopy were obtained in four patients. Postoperative serial digital vascular images (DVI) of the pulmonary artery were obtained in three patients and one patient had a postoperative V/Q scan. For each patient the preoperative and postoperative forced expiratory volume in 1s (FEV₁) were determined to assess the postoperative ventilatory recovery. At bronchoscopy all patients had a patent bronchial anastomosis. At postoperative DVI, in three patients, vascularization of the residual left lung was delayed and less intense compared with the non-operated right lung. Postoperative V/Q scan, in one patient, showed reduced ventilation and perfusion of the residual lung. Preoperative and postoperative FEV₁ of the four patients were 2688/1998 ml, 2154/1752 ml, 2618/2100 ml and 2277/2015 ml. Operative mortality was zero. One patient had a postoperative atelectasis of the left lower lobe. In our series, ventilation and vascularization of the reimplanted and revascularized left lower lobe were reduced. But, in our opinion, the preserved residual lung parenchyma was still a relevant advantage. [Eur J Cardio-thorac Surg (1996) 10:717-721]

Key words  Sleeve resection • Pulmonary function • Perfusion

Introduction

The sleeve lobectomy, in conjunction with a pulmonary arterial sleeve resection (double sleeve resection), is sometimes used as a surgical alternative to a pneumonectomy in patients with a main bronchus carcinoma with local invasion of the pulmonary artery. The double sleeve resection, however, is technically more complex. But Vogt-Moykopf, Ricci, Belli and their colleagues have elegantly demonstrated that a double sleeve resection is feasible with a 30-day postoperative mortality of 0%–5% [2, 8, 9]. Obviously, the preservation of an unaffected lobe is of potential benefit, but it is unclear whether the reimplanted and revascularized lobe preserves its function. Ricci, Belli and their associates found, in their patients, a normal postop-
operative pulmonary perfusion of the revascularized lobe [2, 8]. But no postoperative spirometric data were available.

The aim of this study was to assess whether the residual lung, after a double sleeve resection, preserved its function as judged by ventilation/perfusion, vascularization and spirometry. This paper describes the postoperative spirometry in four patients, the postoperative serial digital images (DVI) of the pulmonary artery in three patients and the postoperative split pulmonary radionuclide ventilation/perfusion (V/Q) scan in one patient. All four patients had a T2 left upper lobe carcinoma, which was resected with a sleeve lobectomy and pulmonary arterial sleeve resection.

**Material and methods**

Between January 1985 and December 1991, six bronchial and arterial sleeve resections of the left upper lobe were performed. Direct tumor invasion of the pulmonary artery was the indication for the arterial sleeve resection. Postoperatively two patients were referred back to their regional hospitals and were, therefore, not included in this analysis.

Preoperative spirometry and V/Q scan were obtained in all four patients. The V/Q scan was performed with either Xenon 133 or Krypton 81m using large field projections from the anterior and dorsal side. Spirometry was performed with a computerized spirometer.

Thoracotomy was performed using the standard posterolateral approach through the 4th interspace. Hilary and mediastinal lymph nodes were sampled. The decision to perform a double sleeve resection was made intraoperatively in all four patients. The surgical technique of the double sleeve resection, described by Vogt-Moykopf and colleagues [9], was used in our patients. The pericardium was opened and the left pulmonary artery was clamped centrally. The arterial branches to the lingula were divided separately. The main pulmonary artery was completely divided close to the pericardial edge and proximal to the left lower lobe arterial branches (Fig. 1). In this way, the carcinomatous area of the pulmonary artery was completely excised. The superior pulmonary vein was divided. Subsequently the main bronchus was divided and a left upper sleeve lobectomy was performed. The cartilaginous part of the bronchial anastomosis, between the main bronchus remnant and left lower lobe, was anastomosed with interrupted Vicryl 3/0 and the membranous part with Prolene 5/0.

The anastomosis of the pulmonary artery was performed with Prolene 6/0. Prior to completion of the arterial anastomosis, the air was eliminated and the artery was flushed with heparin to prevent any debris or air entrapment. A pedicled pericardial flap was positioned between the arterial and bronchial anastomoses to avoid any arterial abrasion. Intraoperatively, intravenous heparin was started and substituted by acenocoumarol 2–3 days after surgery. Acentocoumarol was continued for at least 3 months. Postoperative bronchoscopy and spirometry was repeated in all four patients. For each patient the preoperative and postoperative forced expiratory volume in 1s (FEV1) were determined to assess the postoperative ventilatory recovery. Three patients (S1, S3, S4) had a postoperative electrocardiographic triggered serial digital vascular imaging (DVI) of the pulmonary artery 17, 20 and 15 days after operation. In one patient (S1) the postoperative DVI was repeated 5 years later. Another patient (S2) had a V/Q scan 17 months after operation. The postoperative electrocardiographic triggered serial DVI of the pulmonary artery was obtained by intravenous injection of 40 ml of telebrix contrast solution followed by serial electrocardiographic triggered computer-derived images of the arterial vascularization of both lungs.

The postoperatively measured FEV1 after a double sleeve resection was compared with the predicted postpneumonectomy FEV1 to assess the actual ventilatory benefit of the double sleeve resection. The predicted FEV1 after pneumonectomy was calculated by subtracting the contribution of the left lower lung (4 segments). The predicted postpneumonectomy FEV1 was calculated as follows: preoperative FEV1×10/14. Follow-up was obtained from the patient files, till December 1994.

**Results**

Patients’ characteristics, follow-up and postoperative complications are summarized in Table 1. The preoperative and postoperative FEV1 (ml) of each patient are listed in Table 2. One patient (S2) had a left lower lobe atelectasis due to persistent mucus retention, which was treated successfully. At postoperative bronchoscopy all patients had a non-deformed bronchial anastomosis with unobstructed access to the left lower lobe.

Postoperative DVI of the pulmonary artery, performed in three patients (S1, S3, S4), showed a patent vascular anastomosis without any distortion, but the vascularization of the residual left lung appeared less intense and delayed compared with the non-operated right lung (Fig. 2). One patient (S1) had a repeat postoperative DVI 5 years later.
Fig. 2 a, b and c are 3 consecutive postoperative electrocardiographic triggered serial digital vascular images (DVI) of the pulmonary artery of patient S4 15 days after operation. The vascularization of both lungs was visualized. In each consecutive DVI image the vascular opacification of the residual left lung appeared to be less intense and delayed, compared with the non-operated right lung. (Patients S1 and S3 had similar DVI images)

Fig. 3 a, b and c are 3 consecutive postoperative electrocardiographic triggered serial digital vascular images (DVI) of the pulmonary artery of patient S1, 5 years after operation. Opacification of the residual left lung still appeared to be reduced, compared with the non-operated right lung

(Fig. 3), but perfusion of the residual left lung had not improved compared to the immediate postoperative DVI.

One patient (S2), with a postoperative V/Q scan, also had reduced ventilation and perfusion radioactivity of the lower lobe (Fig. 4); the calculated contribution of the residual left lung to the total ventilation and perfusion capacity was 12% and 10%, respectively.

Three patients, S1, S3 and S4, were alive 74.0, 56.1 and 40.0 months after operation. One patient died (S2) 24.7 months after operation due to a superior vena cava thrombus. No postoperative hemorrhage had occurred.

The predicted postpneumonectomy FEV₁, and measured post double sleeve FEV₁ for the patients S1, S2, S3 and S4 were 1920/1998 ml, 1538/1752 ml, 1870/2100 ml and 1626/2015 ml, respectively. The calculated ventilatory benefit of the double sleeve resection over a pneumonec-

<table>
<thead>
<tr>
<th>Patient's age (years)</th>
<th>TNM</th>
<th>Postop complications</th>
<th>Follow-up (months)</th>
<th>Death</th>
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<tbody>
<tr>
<td>S1 59.4</td>
<td>220</td>
<td>–</td>
<td>74.0</td>
<td>–</td>
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<tr>
<td>S2 66.0</td>
<td>210</td>
<td>Atelectasis</td>
<td>24.7</td>
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<td></td>
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<td>lower lobe,</td>
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<td></td>
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<td>pneumothorax</td>
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<td>S3 63.8</td>
<td>210</td>
<td>–</td>
<td>56.1</td>
<td>?</td>
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<tr>
<td>S4 78.7</td>
<td>210</td>
<td>Atrial fibrillation</td>
<td>40.0</td>
<td>–</td>
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Table 2 Preoperative and postoperative FEV$_1$ (Operation-spirometry number of days between operation and postoperative spirometry)  

<table>
<thead>
<tr>
<th>Operation-spirometry</th>
<th>FEV$_1$ (ml)</th>
<th>Preoperative</th>
<th>Postoperative</th>
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<tbody>
<tr>
<td>S1a 50</td>
<td>2688</td>
<td>1998</td>
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<tr>
<td>b 338</td>
<td>2688</td>
<td>2091</td>
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<tr>
<td>S2 548</td>
<td>2154</td>
<td>1752</td>
<td></td>
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<tr>
<td>S3 33</td>
<td>2618</td>
<td>2100</td>
<td></td>
</tr>
<tr>
<td>S4 25</td>
<td>2277</td>
<td>2015</td>
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</tr>
</tbody>
</table>

Fig. 4 is a radionuclide ventilation and perfusion scan of patient S2, 17 months after operation. Both the ventilation and perfusion of the left lung were reduced. The calculated contribution of the residual left lung to the total ventilation and perfusion capacity was 12% and 10%, respectively.

Discussion

Our series is much too small for definite conclusions. In all four patients the preoperative V/Q scans showed severe reduction of the ventilation and perfusion radioactivity of the upper part of the left lung. Therefore we assumed that, preoperatively, the upper lobe did not contribute to the lung function and we speculated that the postoperative FEV$_1$ should be identical to the preoperative FEV$_1$. But misinterpretations of the preoperative V/Q scans was a potential bias in this series. The visualization of the lingula on the V/Q scan especially, was sometimes difficult. If the lingula contributed to the ventilatory function preoperatively then the postoperative FEV$_1$ would never have been able to reach the preoperative FEV$_1$ because resection of a functioning lingula (2 segments) will inevitably reduce the postoperative FEV$_1$. This phenomenon is a potential explanation for the difference between the preoperative and postoperative FEV$_1$ in our patients.

The time interval between the postoperative spirometry and operation is probably an important factor which could influence the postoperative spirometric data. After a simple bronchial sleeve resection a complete and stable postoperative ventilatory recovery is reached after approximately 4 months [5]. Whether this observation can be extrapolated to the double sleeve resection is unknown. Belli and colleagues, who performed a double sleeve resection in six patients, have reported satisfactory postoperative spirometric measurements [2]. But the spirometric data of their patients were not specified. In our series the postoperative spirometry of three patients (S1, S3, S4) was performed after 17, 20 and 15 days. In these cases, therefore, the postoperative ventilatory recovery might not yet have been completed. But in two patients (S1, S2) the postoperative ventilatory function still remained subnormal (preoperative and postoperative FEV$_1$ were 2688/2091, 2154/1752 ml), 338 and 548 days after operation. The ventilatory benefit of the double sleeve resection, compared to the standard pneumonectomy, varied between 4% and 24%. This benefit was small but, in our opinion, still relevant.

Perfusion changes of the reimplanted lobe after simple sleeve lobectomy have been described by Wood and colleagues, who performed a sleeve lobectomy in mongrel dogs [10]. They found a disproportionate reduction of the perfusion and oxygen uptake 3 days after operation. Four weeks later, however, the oxygen uptake had returned to normal. Wood and colleagues have postulated that the decreased perfusion of the reimplanted lobe is caused by the interruption of parasympathetic nerves, lymphatic vessels and bronchial circulation [10].

Brusasco and associates performed an upper sleeve lobectomy in eight patients [3]. They reported a proportionate decrease of both the ventilation and perfusion of the reimplanted lung lobe 2 weeks after operation. Angeletti reported an improvement of the perfusion of the reimplanted lobe 3 and 12 months after operation [1]. It is therefore reasonable to assume that after a double sleeve resection the perfusion of the revascularized lung lobe is initially much more affected. Ricci and colleagues found a normal post-
operative pulmonary angiography on the 14th postoperative day in 12 of their 14 patients who underwent either a sleeve resection or patch closure of the pulmonary artery [8]. Belli and colleagues also reported a normal postoperative perfusion scintigram in six patients with a double sleeve resection [2]. Read and associates performed a simple left upper lobectomy with an arterial sleeve resection in six patients [7]. Postoperative ventilation/perfusion scans and pulmonary angiography showed good lobar function and perfusion of the revascularized lung lobe in five patients.

In contrast to these observations, the serial digital vascular images (DVI) of three of our patients showed a reduced and less intense opacification of the vascularization of the residual left lung when compared with the non-operated right lung. The patency of the arterial anastomosis was intact and none of these patients had visible arterial distortion. It is arguable, however, whether the reduced vascularization, visualized by DVI, truly correlates with a reduced function. The lack of postoperative V/Q scans in these three patients was a drawback in this series.

Although a double sleeve resection is technically more difficult than a standard pneumonectomy, the morbidity and mortality after a double sleeve resection are very low. Ricci and Belli and their associates, who performed 12 double sleeve resections, had operative mortalities of zero [2, 8]. Vogt-Moykopf and associates, who have even more extensive experience with angioplastic procedures, reported a 30-day mortality rate of only 5% [9]. This compares favorably with the 6% 30-day operative mortality after standard pneumonectomy [4].

The operative mortality in our series was zero. One patient suffered from an atelectasis of the left lower lobe, which was treated successfully. Median survival after double sleeve resections is approximately 20.1 months, as reported by Vogt-Moykopf and associates [9]. The Ludwig Cancer Study group found a median survival of 2.3 years for T2 N1 disease [6]. The survival of our patients, including the T2 N1 patients, appeared to be similar. Our data suggests that operative mortality and morbidity rates after double sleeve resections are acceptable. Although ventilation/perfusion and vascularization of the reimplanted and revascularized lung lobe appeared to be reduced, we still consider the preserved lung parenchyma a relevant functional advantage. Larger series, however, are needed to establish the precise value of the double sleeve resection.

References