Introduction

Atrial fibrillation is relatively common after any type of surgery and is associated with between 3.8% and 37% of operations involving thoracic organs (excluding heart surgery).1 The incidence of atrial fibrillation after lobectomies is between 10% and 20% and approaches 40% after pneumonectomies.2

Atrial fibrillation is associated with higher morbidity, greater risk of cerebrovascular accident, and longer hospital stay and, therefore, higher hospital costs, as well as with increased perioperative mortality and worse long-term survival.1,4

A series of risk factors have been identified that are associated with presentation of atrial fibrillation after thoracic surgery.3,4

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**Risk Factors for Atrial Fibrillation After Thoracic Surgery**

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**OBJECTIVE:** To determine the risk factors for atrial fibrillation after lung resection.

**PATIENTS AND METHOD:** Between January 2002 and December 2003, 149 patients underwent lung resection in our hospital. For all these patients, clinical, surgical, analytical, and oncological data were prospectively collected. The data were subjected to univariate analysis.

**RESULTS:** The mean (SD) age of the 127 men (85.2%) and 22 women (14.8%) who underwent lung resection was 61.8 (12.3) years (range, 17-79 years). Atrial fibrillation was documented in 17 patients (11.4%). Mortality at 30 days was 8.1%. The following risk factors for atrial fibrillation were identified: age 70 years or older (P<.0004), prior heart disease (P<.005), patients undergoing operations for lung cancer (P<.04), and type of resection—right bilobectomy (P<.05) and left pneumonectomy (P<.03). Hypertension, chronic obstructive pulmonary disease, and lung cancer stage were not risk factors. Likewise, systematic lymph node dissection and other forms of lung resection were not risk factors.

**CONCLUSIONS:** After lung resection, atrial fibrillation is a common complication that seems to be associated with old age, history of heart disease, operations for lung cancer, left pneumonectomy, and right bilobectomy. The identification of these risk factors may encourage prospective studies that assess the use of antiarrhythmic drugs to prevent atrial fibrillation during chest surgery.

**Key words:** Atrial fibrillation. Lung resection. Complications. Risk factors. Lung cancer.

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**Factores de riesgo en el desarrollo de fibrilación auricular tras cirugía torácica**

**OBJETIVO:** Determinar los factores de riesgo en la fibrilación auricular (FA) tras la resección pulmonar.

**PACIENTES Y MÉTODO:** Entre enero de 2002 y diciembre de 2003 se realizaron en nuestro servicio 149 resecciones anatómicas pulmonares. Se recogieron prospectivamente las características clínicas, quirúrgicas, analíticas y oncológicas de todos los pacientes intervenidos. Se realizó un análisis univariante de todas las variables registradas.

**RESULTADOS:** La edad media (± desviación estándar) de los pacientes operados –127 varones (85,2%) y 22 mujeres (14,8%)– fue de 61,8 ± 12,3 años (rango: 17-79). Se detectaron 17 casos de FA (11,4%). La mortalidad a los 30 días fue del 8,1%. Se detectaron los siguientes factores de riesgo de presentar FA: edad ≥ 70 años (p < 0,0004), enfermedad cardíaca previa (p < 0,005), pacientes operados por carcinoma broncogénico (p < 0,04) y tipo de resección —bilobectomía derecha (p < 0,05) y neumonectomía izquierda (p < 0,03)—. No fueron factores de riesgo la hipertensión arterial, la enfermedad pulmonar obstructiva crónica, el estadio del carcinoma broncogénico, la disección mediastínica sistémática ni otro tipo distinto de resección pulmonar.

**CONCLUSIONES:** La aparición de FA después de la resección pulmonar anatómica es una complicación frecuente que parece asociarse en nuestra serie a edad avanzada, antecedentes de cardiopatía, intervención por carcinoma broncogénico, neumonectomía izquierda y bilobectomía derecha. La identificación de estos factores de riesgo puede ser de utilidad para iniciar estudios prospectivos encaminados a valorar el uso de fármacos antiarrítmicos para prevenir esta complicación.

**Palabras clave:** Fibrilación auricular. Resección pulmonar. Complicaciones. Factores de riesgo. Cáncer de pulmón.
surgery. These are old age, prior heart disease, chronic obstructive pulmonary disease (COPD), a history of arrhythmias, and the type of surgery performed.

The aim of this study was to test the hypothesis that presentation of atrial fibrillation after anatomical lung resection significantly depends on preoperative comorbidity factors and to identify these factors and the excess risk.

Patients and Method

Between January 2002 and December 2003, 149 patients underwent lung resection in our hospital. For all these patients, clinical, surgical, analytical, and oncological data were prospectively collected. We excluded all nonanatomical lung resections and exploratory thoracotomies, as well as patients with atrial fibrillation diagnosed prior to surgery. All interventions were performed by classical thoracotomy. Lymph node dissection was not done systematically, that is, some patients underwent systematic dissection, whereas lymph node sampling was done in others. The type of lymph node dissection was left to the discretion of the treating surgeon. Lung function was assessed with the protocol of the Bronchogenic Carcinoma Cooperative Group of the Spanish Society for Pulmonology and Thoracic Surgery (GCCB-S). No patient received prophylaxis for atrial fibrillation.

Age, sex, lung function (absolute and percentage forced expiratory volume in 1 second [FEV1], calculated postoperative FEV1, and absolute and percentage forced vital capacity [FVC]), comorbidity (COPD, heart disease, diabetes mellitus, peripheral vascular disease), reason for resection (lung cancer and its pathological stage, lung metastasis, pulmonary neuroendocrine tumor, pulmonary aspergilloma, benign pathology), type of resection, type of lymph node dissection, prior chemotherapy, appearance of atrial fibrillation and when it presented, length of hospital stay, and mortality and causes of death at 30 days were all prospectively analyzed.

Prior heart disease was defined as a heart condition, including untreated arrhythmias, old myocardial infarction, rheumatic fever with valvular involvement, and heart failure from any cause, diagnosed at any time in life. Peripheral vascular disease was defined according to the criteria established in the GCCB-S protocol. COPD was defined as present when FEV1 was less than 80% of the theoretical value and FEV1/FVC was less than 70%. Chemotherapy was compared with the Student t test for independent variables. Excess risk was estimated with the Mantel-Haenszel test. The level of significance was set at a P value less than .05.

Results

The mean age (SD) of the 127 men (85.2%) and 22 women (14.8%) who underwent surgery was 61.8 (12.3) years (range, 17-79 years). Table 1 shows the most important clinical, oncological, and functional characteristics of these patients. The mean postoperative stay in hospital lasted 9.9 (5.9) days and the mortality rate was 8.1% (12 patients). Causes of death were pneumonia (4 patients), acute myocardial infarction (1 patient), bronchial fistula (3 patients), adult respiratory distress syndrome (3 patients), and pulmonary thromboembolism (1 patient).

Atrial fibrillation was documented after surgery in 17 patients (11.4%), and presented 2 to 3 days after surgery in 14 (82.3%) of these (Figure).

Statistical Analysis

The data were analyzed with the SPSS program, version 11.5. Qualitative variables were compared with the χ² test or the Fisher exact test as appropriate. Quantitative variables were compared with the Student t test for independent variables.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Characteristics of the Patients Analyzed in Our Series*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics</td>
<td>Age, years</td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
<td>22/149 (14.8%)</td>
</tr>
<tr>
<td>Lung function tests</td>
<td>FEV1, L</td>
</tr>
<tr>
<td>FEV1%</td>
<td>83.4 (31.9)</td>
</tr>
<tr>
<td>PpFEV1, L</td>
<td>1.82 (0.67)</td>
</tr>
<tr>
<td>PpFEV1%</td>
<td>62.2 (26.8)</td>
</tr>
<tr>
<td>FVC, L</td>
<td>3.50 (0.93)</td>
</tr>
<tr>
<td>FVC%</td>
<td>105.6 (72.4)</td>
</tr>
<tr>
<td>Disease</td>
<td>Lung cancer</td>
</tr>
<tr>
<td>Metastasis</td>
<td>14 (9.4%)</td>
</tr>
<tr>
<td>Lung carcinoma</td>
<td>5 (3.4%)</td>
</tr>
<tr>
<td>Lung carcinoid tumor</td>
<td>5 (3.4%)</td>
</tr>
<tr>
<td>Benign pathology</td>
<td>2 (1.3%)</td>
</tr>
<tr>
<td>Comorbidity</td>
<td>Heart disease</td>
</tr>
<tr>
<td>Hypertension</td>
<td>51/149 (34.1%)</td>
</tr>
<tr>
<td>COPD</td>
<td>87/149 (58.4%)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>19/149 (12.7%)</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>15/149 (9.3%)</td>
</tr>
<tr>
<td>Lung cancer stage</td>
<td>IA</td>
</tr>
<tr>
<td>IB</td>
<td>45 (36.5%)</td>
</tr>
<tr>
<td>IIA</td>
<td>6 (4.9%)</td>
</tr>
<tr>
<td>IIB</td>
<td>17 (13.8%)</td>
</tr>
<tr>
<td>IIIA</td>
<td>15 (12.2%)</td>
</tr>
<tr>
<td>IIIB</td>
<td>3 (2.4%)</td>
</tr>
<tr>
<td>IV</td>
<td>5 (4%)</td>
</tr>
</tbody>
</table>

*Data expressed as mean (SD) or number (%). FEV1 indicates forced expiratory volume in 1 second; FVC: forced vital capacity; PpFEV1, estimated postoperative FEV1; PpFEV1%, estimated postoperative FEV1% expressed as a percentage; COPD, chronic obstructive pulmonary disease.
Return to sinus rhythm was achieved in 15 patients (88.2%). Only 2 of the patients who developed atrial fibrillation died, though the difference in mortality between patients with and without fibrillation was not statistically significant. The effects of the most important study variables and the results of the statistical comparisons are presented in Table 2. The type of surgery and the incidence of atrial fibrillation are shown in Table 3. The following risk factors for atrial fibrillation were identified: age 70 years or older ($P < .0004$), prior heart disease ($P < .005$), patients undergoing surgery for lung cancer ($P < .04$), and type of resection—right bilobectomy ($P < .05$) and left pneumonectomy ($P < .03$). Excess risk for the variables significantly associated with atrial fibrillation is shown in Table 4. Hypertension, COPD, lung cancer stage, and systematic lymph node dissection or other forms of

### Table 2

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>No Atrial Fibrillation</th>
<th>Atrial Fibrillation</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
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<td>Type of resection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pneumonectomy</td>
<td>20 (83.4%)</td>
<td>4 (16.6%)</td>
<td>.373</td>
</tr>
<tr>
<td>Not pneumonectomy</td>
<td>112 (89.6%)</td>
<td>13 (10.4%)</td>
<td></td>
</tr>
<tr>
<td>Upper lobectomy†</td>
<td>94 (86.2%)</td>
<td>15 (13.8%)</td>
<td>.136</td>
</tr>
<tr>
<td>Lower lobectomy</td>
<td>38 (95%)</td>
<td>2 (5%)</td>
<td></td>
</tr>
<tr>
<td>Side of surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>75 (89.3%)</td>
<td>9 (10.7%)</td>
<td>.766</td>
</tr>
<tr>
<td>Left</td>
<td>57 (87.7%)</td>
<td>8 (12.3%)</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>43 (86%)</td>
<td>7 (14%)</td>
<td>.372</td>
</tr>
<tr>
<td>No</td>
<td>89 (90.8%)</td>
<td>9 (9.2%)</td>
<td></td>
</tr>
<tr>
<td>COPD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>77 (88.5%)</td>
<td>10 (11.5%)</td>
<td>.969</td>
</tr>
<tr>
<td>No</td>
<td>55 (88.7%)</td>
<td>7 (11.3%)</td>
<td></td>
</tr>
<tr>
<td>Prior chemotherapy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>24 (96%)</td>
<td>1 (4%)</td>
<td>.201</td>
</tr>
<tr>
<td>No</td>
<td>108 (87.1%)</td>
<td>16 (12.9%)</td>
<td></td>
</tr>
<tr>
<td>Age, years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 70</td>
<td>100 (93.5%)</td>
<td>7 (6.5%)</td>
<td>.0004</td>
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<tr>
<td>≥ 70</td>
<td>32 (76.2%)</td>
<td>10 (23.8%)</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>112 (88.2%)</td>
<td>15 (11.8%)</td>
<td>.711</td>
</tr>
<tr>
<td>Female</td>
<td>20 (90.9%)</td>
<td>2 (9.1%)</td>
<td></td>
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<tr>
<td>Oncological stage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-II</td>
<td>86 (86%)</td>
<td>14 (14%)</td>
<td>.951</td>
</tr>
<tr>
<td>III-IV</td>
<td>20 (87%)</td>
<td>3 (13.0%)</td>
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<td>Lung function tests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEV,</td>
<td>2.477 (803.0)</td>
<td>2.451 (531)</td>
<td>.904$$</td>
</tr>
<tr>
<td>FEV,%</td>
<td>83.5 (31.9)</td>
<td>85.7 (18)</td>
<td>.764$$</td>
</tr>
<tr>
<td>PpoFEV,</td>
<td>1.825 (747.5)</td>
<td>1.783 (578)</td>
<td>.790$$</td>
</tr>
<tr>
<td>PpoFEV,%</td>
<td>62.2 (26.8)</td>
<td>62 (19)</td>
<td>.977$$</td>
</tr>
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<td>Lymph node dissection</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>No</td>
<td>118 (89.4%)</td>
<td>14 (10.6%)</td>
<td>.369</td>
</tr>
<tr>
<td>Yes</td>
<td>14 (82.4%)</td>
<td>3 (17.6%)</td>
<td></td>
</tr>
<tr>
<td>Disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lung cancer</td>
<td>106 (86.2%)</td>
<td>17 (13.8%)</td>
<td>.044</td>
</tr>
<tr>
<td>Other cancer</td>
<td>26 (100%)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Heart disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>15 (68.2%)</td>
<td>7 (31.8%)</td>
<td>.005</td>
</tr>
<tr>
<td>No</td>
<td>117 (92.2%)</td>
<td>10 (7.8%)</td>
<td></td>
</tr>
</tbody>
</table>

*Data expressed as mean (SD) or number (%).

COPD indicates chronic obstructive pulmonary disease; FEV, forced expiratory volume in 1 second; PpoFEV, estimated postoperative FEV; PpoFEV, estimated postoperative FEV, expressed as a percentage.

†The variable upper and lower lobectomy is related to manipulation of the superior or inferior pulmonary vein. Pneumonectomies and middle lobectomies which involved manipulation of the superior pulmonary vein were counted as upper lobectomies.

‡$\chi^2$ test or Fisher exact test.

§Student t test for independent variables.
GÓMEZ-CARO A ET AL. RISK FACTORS FOR ATRIAL FIBRILLATION AFTER THORACIC SURGERY

Analysis of Atrial Fibrillation and Type of Resection

<table>
<thead>
<tr>
<th>Side</th>
<th>Type of Resection</th>
<th>N</th>
<th>Atrial Fibrillation</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>Pneumonectomy</td>
<td>9 (6%)</td>
<td>0</td>
<td>.54</td>
</tr>
<tr>
<td></td>
<td>Upper lobectomy</td>
<td>40 (26.8%)</td>
<td>5 (12.5%)</td>
<td>.766</td>
</tr>
<tr>
<td></td>
<td>Middle lobectomy</td>
<td>8 (5.4%)</td>
<td>1 (12.5%)</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td>Lower lobectomy</td>
<td>19 (12.8%)</td>
<td>0</td>
<td>.246</td>
</tr>
<tr>
<td></td>
<td>Bilobectomy</td>
<td>8 (5.4%)</td>
<td>2 (25%)</td>
<td>.005</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>84 (56.3%)</td>
<td>8 (9.5%)</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>Pneumonectomy</td>
<td>15 (10.1%)</td>
<td>4 (26.6%)</td>
<td>.037</td>
</tr>
<tr>
<td></td>
<td>Upper lobectomy</td>
<td>29 (19.5%)</td>
<td>2 (6.9%)</td>
<td>.449</td>
</tr>
<tr>
<td></td>
<td>Lower lobectomy</td>
<td>21 (14.1%)</td>
<td>2 (9.5%)</td>
<td>.838</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>65 (43.7%)</td>
<td>8 (12.3%)</td>
<td></td>
</tr>
</tbody>
</table>

*χ² test or Fisher exact test.

Predictive Analysis of Risk of Postoperative Atrial Fibrillation*

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
<th>P†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age ≥ 70 years</td>
<td>2.9 (2.3-3.3)</td>
<td>.001</td>
</tr>
<tr>
<td>Prior heart disease</td>
<td>1.8 (3.2-1.1)</td>
<td>.005</td>
</tr>
<tr>
<td>Lung cancer surgery</td>
<td>2.7 (3.6-1.2)</td>
<td>.044</td>
</tr>
<tr>
<td>Left pneumonectomy</td>
<td>1.2 (2.3-0.9)</td>
<td>.037</td>
</tr>
<tr>
<td>Right bilobectomy</td>
<td>1.7 (3.2-1.1)</td>
<td>.005</td>
</tr>
</tbody>
</table>

*OR indicates odds ratio; CI, confidence interval.
†Mantel-Haenszel test.

We did not find a significant relationship between estimated preoperative or postoperative FEV₁ values, regardless of whether expressed as absolute values or as percentages, and atrial fibrillation. However, a relationship between the severity of COPD and a higher risk of atrial fibrillation has been reported in the literature. Hypoxemia appears both in the preoperative and postoperative period, and so has also been associated with this arrhythmia. A number of studies have identified prior heart disease, in particular ischemic heart disease and congestive heart failure of varying causes, as a risk factor. The mechanism by which arrhythmias occur may be related to atrial stimulation in the sutured region of the sectioned pulmonary vein, a region that a number of prestigious studies have identified as a trigger zone. In fact, in up to 94% of cases, ectopic activity leading to atrial fibrillation originates in the pulmonary veins, in particular, in the superior pulmonary veins, and specifically 2 cm to 4 cm inside these veins. Some studies report a higher incidence in pneumonectomies and in these cases, the arrhythmias might be related to intrapericardial dissection of the superior pulmonary vein. Other studies do not find any relationship between the type of pulmonary resection and this arrhythmia. In our series, this association was not significant, though our service is very reticent about performing right pneumonectomies in patients aged over 70 years. In addition, in our study, upper lobectomies were not more strongly associated with atrial fibrillation, even though such procedures involve more extensive manipulation of the superior pulmonary vein, where trigger zones might be expected more often for electrophysiological reasons. The large difference in the incidences of atrial fibrillation between anatomical and nonanatomical lung resections, which do not normally involve manipulation of periatrial or pericardial structures, could also be largely explained by this reasoning.

To the best of our knowledge, no study has reported tumor stage as a determining factor, in contrast to the type of lung resection and lymph node dissection, which have been associated with atrial fibrillation. Systematic lymph node dissection also appears in the literature as a risk factor for the development of atrial fibrillation. This could be related to lesion of vagal nerve branches, which are damaged on removing adipose-lymphoid tissue from mediastinal areas and areas around the lungs. Such procedures are nevertheless essential for reliable lung cancer staging.

The appearance of atrial fibrillation after surgery can lead to increased comorbidity. To avoid this risk, prophylaxis to prevent or reduce the chance of atrial fibrillation appearing has been considered. Such prophylactic agents include digoxin, β-blockers, amiodarone, and diltiazem. In high-risk patients, only amiodarone and diltiazem have been shown to provide effective prophylaxis against atrial fibrillation. Amiodarone is considered the safest and most effective agent for treating atrial fibrillation. These studies
failed to reflect, however, a decrease in costs or length of stay in hospital with prophylaxis.

In conclusion, the appearance of atrial fibrillation after anatomical lung resection is a common complication that is associated with advanced age, history of heart disease, lung cancer operations, left pneumonectomy, and right bilobectomy. Identification of these risk factors could be useful for planning prospective studies that aim to assess the use of antiarrhythmic drugs to prevent atrial fibrillation.

REFERENCES