Lung Lobectomy Affects Electrocardiographic Intervals

Ryosuke Usuda1, Makoto Nonaka1, Kaoru Tanno2, Takashi Suzuki1 and Mitsutaka Kadokura3

Abstract: After lung lobectomy, the residual thoracic cavity is filled by expansion of the remaining lobes and by mediastinal shifting. The mediastinal shift contributes to a change in the anatomical position of the heart. This change may affect electrocardiographic (ECG) findings but the relationship has not been examined. In this study, ECG intervals, including RR, P, PR, S-Tp, QRS, and QTc intervals, were analyzed before and after 86 lung lobectomies, consisting of 27 right upper (RU), 10 right middle (RM), 12 right lower (RL), 25 left upper (LU), and 12 left lower (LL) lobectomies. Persistent postoperative arrhythmia was observed in 10 patients (12%), all with atrial fibrillation. After RU lobectomies, the RR, PR, and S-Tp intervals became shorter. After RM lobectomies, the RR and QTc intervals became shorter and the P and PR intervals were prolonged. RL, LU, and LL lobectomies did not appreciably affect the ECG intervals. The post/pre-operative ratio of the P and PR intervals were greater following RM lobectomy than following RU or RL lobectomy. The post/pre-operative ratio of the QTc interval was smaller after RM lobectomy than after RL lobectomy. Lung lobectomy affected ECG intervals and the pattern of change varied depending on the lobe resected. Resection of the RM lobe, the lobe that is anatomically next to the right atrium, prolonged the PR interval and the change in pattern was different from RU or RL lobectomies. The change in the anatomical position of the heart following lung lobectomy may contribute to the changes in ECG intervals.

Key words: electrocardiogram, right middle lobe, right atrium, PR interval, QTc interval

Introduction

In the treatment of lung cancer, surgical resection, namely lung lobectomy or pneumonectomy, is a standard procedure. After lung lobectomy, the residual thoracic cavity is filled by an expansion of the remaining lobes, an elevated diaphragm, a shrinking of the thoracic cage, and a mediastinal shifting. The pattern of the mediastinal shift is associated with the resected lobes, and this mediastinal shift contributes to a change in the anatomical position

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of the heart. This altered position may cause changes in the electrocardiogram (ECG) but the effect is not obvious. In this study, we examined the ECG of patients before and after lung lobectomy, and analyzed changes in the ECG intervals. The relationship between the changes in the ECG intervals and the resected lobes are discussed.

**Patients and Methods**

Preoperative ECGs were obtained from patients before they underwent single lung lobe resection and lymph node dissection for the treatment of lung cancer. Postoperative ECGs were obtained from patients six months after surgery, following discharge from hospital, with the remaining lung lobes fully expanded. Patients, who had cardiovascular disease, arrhythmia, emphysema, or fibrous lung disease preoperatively, were excluded by preoperative examinations, such as echocardiography, pulmonary function tests, computed tomography, and scintigraphy. Patients who needed pericardial dissection at surgery were also excluded. Eighty-six patients, consisting of 65 males and 21 females, were included in this study (Table 1). In total, 27 right upper (RU) lobectomies, 10 right middle (RM) lobectomies, 12 right lower (RL) lobectomies, 25 left upper (LU) lobectomies, and 12 left lower (LL) lobectomies were performed (Table 1). The RR interval, P wave interval, PR interval, S-Tp interval, QRS interval, and QT interval were measured digitally and the corrected QT interval (QTc) was calculated using the following formula:

$$\text{QTc interval} = \frac{\text{QT interval}}{\text{RR interval}^\frac{1}{2}}$$

Additionally, the changing pattern of the P wave associated with RM lobectomies was studied. The interval, form, amplitude, and axis of the P wave were examined.

All data are expressed as the mean ± standard error of the mean. Analysis of variance was used for statistical assessment and the P-value of significance was 0.05.

**Results**

Persistent postoperative arrhythmia was observed in 10 out of the 86 patients (12%) and all these patients had atrial fibrillation. Of the patients that developed arrhythmias, four had undergone RU lobectomy (4/27; 15%), 3 had undergone LU lobectomy (3/25; 12%), and 3 had undergone LL lobectomy (3/12; 25%) (Table 1). The patients with
Atrial fibrillation consisted of eight males (8/65; 12%) and 2 females (2/21; 10%), and there was no significant gender difference. These 10 patients were given digoxin orally from the onset of the atrial fibrillation. Preoperative ECG intervals were not different between the patients with postoperative arrhythmia and the patients without postoperative arrhythmia. These 10 patients were excluded from the following analyses, leaving 76 patients (23 RU lobectomies, 10 RM lobectomies, 12 RL lobectomies, 22 LU lobectomies, and 9 LL lobectomies).

For the 76 patients, the preoperative median heart rate was 68.7 ± 1.3 beats/min, while the postoperative median heart rate was 76.0 ± 1.7 beats/min. The RR, PR, and S-Tp intervals were shortened by RU lobectomy (all \( P < 0.05 \), Table 2). After RM lobectomy, the P wave interval and PR interval were prolonged (\( P < 0.01 \) and \( P < 0.05 \), respectively), while the RR and QTc intervals were shortened (both \( P < 0.05 \), Table 2). The PR interval before RM lobectomy was significantly shorter than that before RU lobectomy (\( P < 0.05 \)). The P wave interval after RM lobectomy was longer than that after RU lobectomy (\( P < 0.05 \)). The QTc interval after RM lobectomy was significantly shorter than that after RU or RL lobectomies (\( P < 0.05 \) and \( P < 0.01 \), respectively, Table 2). RL, LU, and LL lobectomies did not change any of the ECG intervals (Tables 2 and 3).

The post/pre-operative ratios of the ECG intervals were compared after resection of different lung lobes (Tables 2 and 3). The P wave interval ratio and PR interval ratio were significantly greater following RM lobectomy than following RU or RL lobectomies (Table 2, Figs. 1 and 2). The QTc interval ratio was smaller following RM lobectomy compared to RL lobectomy (\( P < 0.05 \)). These three ratios were not different between RU lobectomy and RL lobectomy.

The change in the P waveform in RM lobectomy cases was analyzed in lead II. Shortening of the P wave interval, or biphasic or negative P waves were not observed after RM lobectomy. Amplitude of the P wave in RM lobectomy cases was 0.068 ± 0.006 mV preoperatively, and was not changed postoperatively (0.070 ± 0.009 mV). The preoperative axis of the P wave was 57 ± 7 degrees and the postoperative axis was unchanged at 53 ± 10 degrees.

No clinical symptoms accompanied any of the changes in ECG intervals.

**Discussion**

Lung lobectomy shifts the mediastinum and the pattern of shifting varies with the different resected lobes. We previously reported that lung resection affects the position of the heart and great vessels. The present study quantifies the effect of a single lobe resection on the ECG findings, and the change in ECG intervals after RM lobectomy differs from the patterns seen following resection of the other lung lobes, as shown in Fig. 1 and 2. Since the RM lobe is located next to the right atrium anatomically, RM lobectomy may affect the right atrium more than the other lobe resections.

The RR interval reflects the heart rate. In this study, the RR interval was shortened after each lobectomy, especially after RM lobectomy. This shortening of the RR interval...
Table 2. Electrocardiographic intervals before and after right lung lobectomy

<table>
<thead>
<tr>
<th></th>
<th>Preoperative (msec)</th>
<th>Postoperative (msec)</th>
<th>Post / Pre ratio (%)</th>
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<tbody>
<tr>
<td></td>
<td>RR</td>
<td>P</td>
<td>PR</td>
</tr>
<tr>
<td>Right upper lobectomy (n = 23)</td>
<td>870 ± 29</td>
<td>96 ± 2</td>
<td>176 ± 6#</td>
</tr>
<tr>
<td>RR</td>
<td>794 ± 29*</td>
<td>97 ± 3#</td>
<td>165 ± 4*</td>
</tr>
<tr>
<td>PR</td>
<td>92.7 ± 3.5</td>
<td>101.6 ± 2.8#</td>
<td>94.7 ± 2.2#</td>
</tr>
<tr>
<td>S-Tp</td>
<td>84.4 ± 5.9</td>
<td>118.4 ± 4.2</td>
<td>108.4 ± 3.5</td>
</tr>
<tr>
<td>QRS</td>
<td>93.8 ± 5.5</td>
<td>101.9 ± 3.1#</td>
<td>96.9 ± 3.4#</td>
</tr>
<tr>
<td>QTc</td>
<td>97.6 ± 2.8</td>
<td>98.2 ± 2.2</td>
<td>98.2 ± 2.4</td>
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</tbody>
</table>

Values are mean ± standard error of the mean; *P < 0.05 vs. preoperative; #P < 0.05 vs. right middle lobectomy.

Table 3. Electrocardiographic intervals before and after left lung lobectomy

<table>
<thead>
<tr>
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<th>Preoperative (msec)</th>
<th>Postoperative (msec)</th>
<th>Post / Pre ratio (%)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
<td>P</td>
<td>PR</td>
</tr>
<tr>
<td>Left upper lobectomy (n = 22)</td>
<td>879 ± 35</td>
<td>96 ± 3</td>
<td>169 ± 6</td>
</tr>
<tr>
<td>RR</td>
<td>794 ± 35</td>
<td>95 ± 2</td>
<td>164 ± 6</td>
</tr>
<tr>
<td>PR</td>
<td>92.9 ± 4.7</td>
<td>99.4 ± 2.5</td>
<td>98.3 ± 4.2</td>
</tr>
<tr>
<td>S-Tp</td>
<td>95.8 ± 6.7</td>
<td>94.6 ± 5.2</td>
<td>94.7 ± 4.0</td>
</tr>
<tr>
<td>QRS</td>
<td>98.2 ± 2.2</td>
<td>98.2 ± 2.2</td>
<td>98.2 ± 2.2</td>
</tr>
<tr>
<td>QTc</td>
<td>97.6 ± 2.8</td>
<td>97.6 ± 2.8</td>
<td>97.6 ± 2.8</td>
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</table>

Values are mean ± standard error of the mean.
Fig. 1. The electrocardiogram (ECG) of a patient before (a, b) and 6 months after (c, d) undergoing a right middle lung lobectomy. Pulse rate was raised from 74 to 96 beats per minute (a, c) but PR interval was prolonged from 160 to 194 msec (b, d).

Fig. 2. Change in PR and QTc intervals after right upper (RU), right middle (RM), and right lower (RL) lung lobectomies. After RM lobectomy, the PR interval was prolonged and the QTc interval was shortened compared to RU or RL lobectomy.
reflects the postoperative tachycardia. The postoperative ECG was taken six months after
the operation and it was thought that the increase in heart rate was permanent, but did not
cause any clinical symptoms. The normal P wave is a low-amplitude wave that is produced
by activation of the atria. Longer intervals are associated with atrial enlargement or intra-
atrial conduction defects. The change in the anatomy of the mediastinum and heart after
RM lobectomy may alter the right atrium and P interval because the right atrium is next to
the RM lobe through the pericardium. This hypothesis is supported by the fact that the P
interval was unchanged after RU and RL lobectomies.

The PR interval measures the time required for the impulse to travel from the atrial
myocardium adjacent to the sino-atrial node to the ventricular myocardium adjacent to the
fibers of the Purkinje network. The PR interval is inherently heart-rate dependent. After
RU lobectomy, the PR interval was significantly shortened and this may be due to the fact
that the RR interval was significantly shortened after RU lobectomy. In the same way, after
RL lobectomy, the PR interval was slightly shortened and this may also be a result of slight
shortening of the RR interval after RL lobectomy. However, after RM lobectomy, the PR
interval was prolonged, although the RR interval was shortened. The post/pre-operative
ratio of the PR interval was greater following RM lobectomy than following RU or RL
lobectomy. Since the S-Tp interval was not changed after RM lobectomy, this prolongation
of the PR interval after RM lobectomy may be due to a significant prolongation of the P
wave. These changes in the ECG intervals could reflect anatomic changes in the mediasti-
um and heart since the conduction speed within the heart is not changed after lobectomy.

The QT interval represents electrical systole and is the time required for depolarization
and repolarization of the ventricles to take place. Since tachycardia shortens the QT
interval, the interval is corrected by the RR interval and is demonstrated as the QTc inter-
val. After each lobectomy, the QTc interval was unchanged or shortened in our study. The
QT interval is shortened by digitalis, hypercalcemia, or hyperpotassemia, however, most of
our patients did not have these conditions. The lower limits of a normal QTc interval have
not been well defined.

Cardiac arrhythmia is a well-recognized complication after lung resection. The mecha-
nism of postoperative arrhythmia is unknown, but various factors are proposed, such as
postoperative hypoxia, concomitant cardiopulmonary disease, the extent of surgery, right ven-
tricular dilatation, pulmonary hypertension, and increased right heart pressure. Postoper-
avie arrhythmias are usually of atrial origin, and ventricular arrhythmias are uncommon.
Postoperative atrial fibrillation is not correlated with major morbidity and mortality and
many cases resolve spontaneously. In our study, patients who had cardiovascular disease,
arrhythmia, emphysema, or fibrous lung disease preoperatively were excluded because
we wanted to exclude these preoperative cardiopulmonary factors from our analysis of the
relationship between the preoperative ECG intervals and postoperative arrhythmia. We also
excluded patients who received pneumonectomy or partial resection of the lung because this
study was performed to examine the change in ECG intervals associated with each lobe resection. Clinically, partial resection of the lung is a palliative operation for compromised patients\(^ {11}\) and pneumonectomy often causes postoperative arrhythmia\(^ {9,10}\). The exclusion of these patients may be a reason for the low rate (12%) of postoperative persistent arrhythmia in our study when compared with previously reported rates of 10%–30%\(^ {9,10,12}\). This study shows that evaluation of the preoperative ECG interval is not useful for predicting postoperative arrhythmia if the patient has no cardiopulmonary complication before surgery.

This report is the first study to examine the relationship between lobectomy and ECG intervals and additional electrophysiological study is warranted\(^ {13,14}\). In conclusion, lung lobectomy affects ECG intervals and the pattern of change varies depending on the lobe resected. In particular, resection of the RM lung lobe, the lobe anatomically next to the right atrium, causes a prolonged PR interval and the changing pattern is different from that seen after RU or RL lobectomies.

References

6) Bazett HC: An analysis of the time relations of electrocardiograms. \textit{Heart} 7 : 353–370 (1920)