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Evaluation of the anatomical and electrical axis of the heart after pneumonectomy

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ABSTRACT

Aim: To investigate the position of the heart after pneumonectomy and, also to find out how the changes in the electrical axis of the heart contribute for the possible electrocardiographic and echocardiographic changes.
Methods: Ninety-eight patients with pneumonectomy were included to this observational study. To calculate the rotation of the heart and angle measurement two perpendicular lines, one septal and another atrioventricular, were drawn on the images acquired from thoracic computed tomography. Thoracic CT were taken at every 3 months for the first two years. On electrocardiograms net QRS vectors, amplitudes of p waves, findings of right and left ventricular hypertrophy, and other possible changes were recorded.
Results: The mean age of all patients was 55.51 ± 8.9. Right pneumectomy was performed in 40 (57%) and left pneumonectomy in 30 cases (43%) cases. There was no significant change regarding both the angle of rotation and the amount of pleural effusion between the findings of the second and first year after the operation. The QRS shift was significantly more pronounced in patients with left pneumonectomies than right pneumonectomies. On echocardiography these cases showed right ventricular hypertrophy and increased pulmonary artery pressures in the second year when compared to the preoperative period.
Conclusions: The current study showed that many significant changes occurred in the electrocardiographic and echocardiographic parameters of the heart after pneumonectomy.

Key words: Pneumonectomy, heart, anatomy, electrical axis, computed tomography, electrocardiography, and echocardiography.

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Introduction

Pneumonectomy is the removal of the whole lung in the ipsilateral hemithorax due to any cause such as malignancy, tuberculous or non-specific infections, and trauma [1,2]. It was first performed by Graham and Singer in 1933 and has been the routine procedure until 1950 for the treatment of lung cancer [3]. A lot of changes occur after pneumonectomy including mediastinal shift and elevation of the hemidiaphragm in the ipsilateral hemithorax that lead to change of the heart, great vessels, liver, spleen, and stomach [4]. The process takes months to years to occur due to the production of fibrotic tissue in the empty pleural space, intrathoracic pressure changes, with elevation of the diaphragm and

overdistension of the remaining lung, the heart and mediastinum shift to the side that was operated on [5,6].

The effects of pneumonectomy on the anatomical and the electrical axis of the heart have not been studied much. The current study aims to investigate the position of the heart after right or left pneumonectomy and, also to find out how the changes in the electrical axis of the heart contribute for the possible electrocardiographic and echocardiographic changes.

Materials and methods

The study was conducted at Istanbul Training and Research Hospital, Turkey. The current study was approved by the Hospital Ethical Committee (Date and decision no: 2019/1660). Written consent of the participants was obtained.

Study population

In this observational study, 98 consecutive patients who had pneumonectomy due to lung cancer, bronchiectasis, aspergillosis or trauma were analyzed. All cases had thorough physical examinations and routine laboratory tests. Lung spirometry tests were performed in all cases to document forced expiratory volume in 1 second (FEV1), vital capacity (VC) and maximum oxygen uptake during exercise (VO2max) was calculated. After double lumen endotracheal intubation standard posterolateral thoracotomy was performed and routine right or left pneumonectomy was achieved.

Computerized tomography of thorax (CTT) was performed for all cases preoperatively. All CTT were evaluated by a specialized chest radiologist. Patients were routinely examined by a staff cardiologist, and electrocardiograms and echocardiography were analyzed. At the follow-up visits (every 3 months for the first two years) physical examinations and routine blood tests were performed, and thoracic CT (every 3 or 6 months for the first two years, on the basis of the etiology) were taken routinely.

Computerized Tomography Evaluation

All CTT both before and after the operation were taken by the same 64-slice CT scanner (Aquilion 64, Toshiba Medical Systems Europe, The Netherlands). The characteristics of the pictures were 0.5/0.3 collimation, 120 kv, 150 mA, pitch 0.75, 240 mm FOV, and 512 matrices. Tera-Recon Aquarius (San Mateo, California) processed the acquired data and calculated the axis angles, shift and rotation of the heart, and the amount of epicardial fat tissue and pleural effusion.

To calculate the rotation and angle measurement two perpendicular lines, one septal and another atrioventricular, were drawn on the images acquired from thoracic CT without contrast medium. The intercept of the two lines was accepted as the middle point (Figure 1A). Another line was drawn from the middle of the sternum to the spinous processes posteriorly (sterno-spinous line). The angle between the sterno-spinous line and septal line was the rotation line (Figure 1B). The distance between sterno-spinous line and the middle point was considered as the amount of shift (Figure 1C). All calculations were performed by RadiAnt Dicom Viewer application (Poznan, Poland). The measurements of a patient are presented in figure 2 as an example.

Electrocardiographic and echocardiographic evaluation

The preoperative and postoperative electrocardiographs (ECG) were recorded and evaluated by an experienced cardiologist. On ECG's net QRS vectors, amplitudes of p waves, findings of right and left ventricular

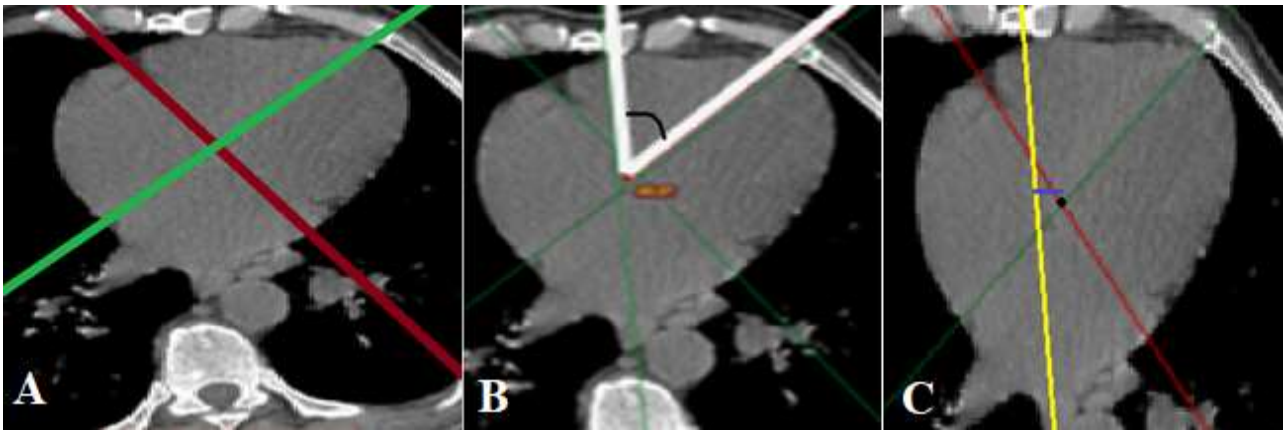

Figure 1. A) Drawing of two perpendicular lines, one septal and another atrioventricular. The intercept of the two lines was accepted as the middle point. **B)** Sterno-spinous line drawn from the middle of the sternum to the spinous processes posteriorly. The angle between the sterno-spinous line and septal line was the rotation line. **C)** The distance between sterno-spinous line and the middle point was considered as the amount of migration.

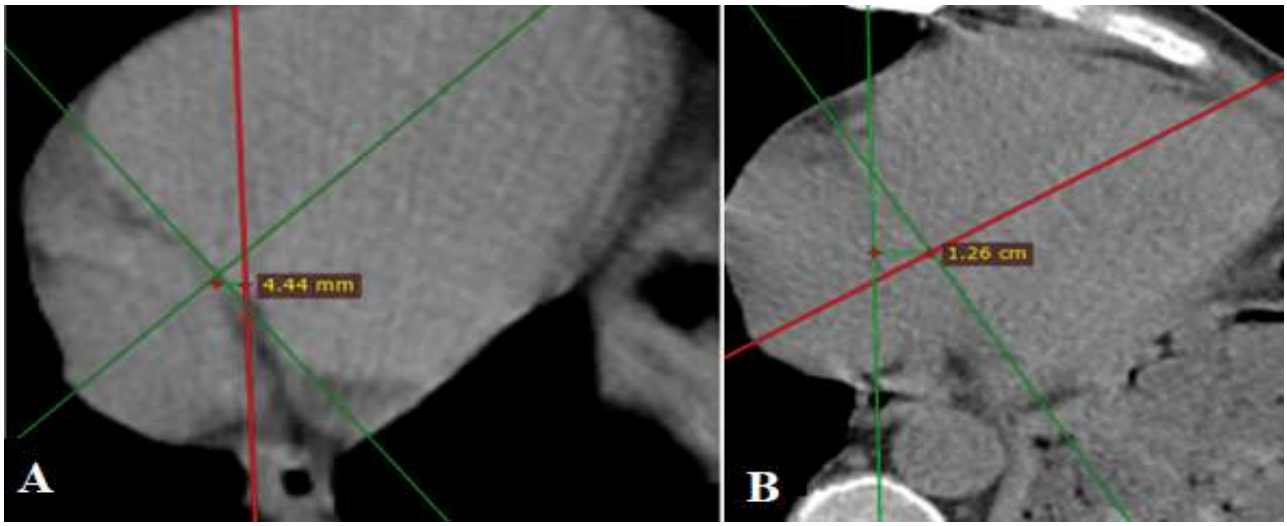

Figure 2. In a 60-year-old male patient who was operated due to left upper consolidated lung carcinoma, preoperative heart shift was 4.44 mm **(A)** to the right, while it was measured as 12.6 mm **(B)** to the left in the postoperative 2-year follow-up.

hypertrophy, and other possible changes were recorded. Net QRS electrical vectors were calculated based on the findings on D1 and D3 derivations. All patients underwent echocardiographic examination (Philips IE33 F Cart Echocardiography System) by the same cardiologist.

Statistical analysis

The continuous variables were expressed as mean and standard deviation and categorical variables as frequencies and percentages. Repeated measures of ANOVA test (post-hoc: Bonferroni test) was used for comparison of the means of the groups before and after the procedure when the data were normally distributed, and otherwise Friedman test (post-hoc: Dunn's test) was used. The proportional differences of categorical variables between follow-ups were analyzed using the Cochran's Q test. The test was considered significant when

calculated p value is less than 0.05. IBM SPSS Statistics, version 23 for Windows (IBM Corporation, Armonk, NY, USA) was used for calculations.

Results

During the follow-up four patients in the first year and 24 others in the second year after the operation died and excluded from the study. The remaining seventy cases formed the study population. Male patients dominated the study group (64 cases, 91%) and the mean age of all patients was 55.51 ± 8.9. Right pneumectomy was performed in 40 (57%) and left pneumonectomy in 30 cases (43%) cases. All cases were followed for an average of 2 years.

The angle of rotation did not change significantly in the first year after the operation when compared to the preoperative findings. In patients with right pneumonectomy the amount of anatomical migration was statistically higher in the second year after the operation than the amount after the first year (*17.73 ± 18.47 vs 24.73 ± 18.19; P=0.001)*. There was no significant change regarding both the angle of rotation and the amount of pleural effusion between the findings of the second and first year after the operation (Table 1).

On ECG, the net QRS shift was tended to towards the same side in patients with pneumonectomy, but this trend did not show statistical significance (Table 2). The QRS shift was significantly more pronounced in patients with left pneumonectomies than right pneumonectomies *(p=0.001)*. However, in both groups the QRS shift showed a tendency towards normal in the late period. In the late period on ECG right pneumonectomy patients showed findings of right ventricular hypertrophy. When examined with echocardiography these cases showed right ventricular hypertrophy and increased pulmonary artery pressures in the second year when compared to the preoperative period. Left ventricle ejection fraction showed no differences in either groups when compared to the preoperative findings (Table 2).

Table 1. Chest CT findings before and after right and left pneumonectomy.

Parameters	Preoperative	Postoperative		*P value*	
		1st year	2nd year	*Preoperative vs 1st year*	*1st year vs 2nd year*
Angle of rotation R	69.80 ± 9.05	71.02 ± 9.82	70.45 ± 12.66	*0.391*	*0.822*
L	67.31 ± 7.07	74.47 ± 18.18	73.32 ± 19.41	*0.072*	*0.710*
Migration (mm) R	5.22 ± 13.40	17.73 ± 18.47	24.73 ± 18.19	***0.012***	***0.001***
L	7.41 ± 16.71	25.99 ± 13.41	31.96 ± 13.13	***0.001***	*0.086*
Pleural effusion (ml) R	1.61 ± 5.08	50.32 ± 35.09	42.40 ± 24.85	***0.001***	*0.247*
L	5.78 ± 14.40	47.34 ± 27.13	34.15 ± 22.40	***0.001***	***0.044***

Table 2. Heart rate and QRS vector shift parameters before and after right and left pneumonectomy.

Parameters	Preoperative	Postoperative		*P* value	
		1st year	2nd year	Preoperative vs 1st year	1st year vs 2nd year
HR R	49.80 ± 9.05	51.02 ± 9.82	50.45 ± 12.66	0.391	*0.180*
L	47.31 ± 7.07	54.47 ± 18.18	53.32 ± 19.41	0.072	*0.219*
QRS shift R	11.8±26.6	15.7±29.9	14.9±31.2	0.793	*0.826*
L	5.22 ± 13.40	17.73 ± 18.47	14.73 ± 18.19	***0.012***	***0.001***
PAP (mmHg) R	19.31±2.3	35.78±15	38±14	***0.001***	***0.001***
L	18.26±3.1	29.43±9	32.25±11	***0.001***	***0.001***
LV EF R	61±9	57±11	56±14	*0.070*	*0.060*
L	63±8	59±10	58±12	*0.090*	*0.060*
R/S R	5 (12.5%)	13 (32.5%)	16 (40.0%)	***0.030***	***0.010***
L	4 (13.3%)	9/ (30.0%)	11 (36.7%)	*0.200*	*0.090*
AF R	0	2 (5.0%)	0	*0.500*	*0.500*
L	0	1 (3.3%)	1 (3.3%)	*0.990*	*0.999*
P pulmonale R	0	2 (5.0%)	1 (2.5%)	*0.500*	*0.910*
L	0	2 (6.7%)	1 (3.3%)	*0.614*	*0.987*

R: Patients with right pneumonectomy, L: Patients with left pneumonectomy, HR: Heart rate, PAP: Pulmonary artery pressure, LVEF: Left ventricular ejection fraction, AF: Atrial fibrillation

Discussion

In this study showed that [1] at the first year of visit thorax CT showed that the heart shifted to the site pneumonectomy. But interestingly at the second year instead of further shift, the heart moved slightly backwards possibly due to the collection of pleural effusion [2]. The rotational changes of the heart detected on the chest CT did not differ after the first year and second year compared to the preoperative findings. At the first postoperative year, the net QRS vector which was dependent on the left ventricle shifted to the left and right after left and right pneumonectomy, respectively. However, at the second postoperative year there was no statistical difference in the net QRS vector between first and second year.

The anatomical and functional changes of the heart, and the subsequent changes on the ECG after pneumonectomies due to various reasons were studied extensively in the literature. Decrease of pulmonary capacity and cardiac

derangements cause some signs and symptoms to occur after lung resections and it is sometimes difficult to understand the source whether cardiac or pulmonary. Routine outpatient visits after the operation with the use of accessible tools like chest CT, electrocardiogram, and echocardiography can make it possible to perceive the possible complications early [7-9].

There are only a few studies addressing the changes on ECG occurring due to shift of the heart and rotation of the heart around its axis after pneumonectomy [10]. In the current study four patients developed atrial fibrillation. The possible reason for atrial fibrillation could be the inflammation of the pulmonary veins and atrium developing during the early postoperative period. The increase in P wave dispersion which was reported on the literature could explain the situation [11]. Two limitations of our study were lack of P wave dispersion and atrial pressure measurements. Atrial fibrillation was the most frequent cardiac arrhythmia after pneumonectomy in the literature, and in 98% of the cases the situation resolves spontaneously or with medical therapy [12]. However, there might be some cases with atrial fibrillation that could not be detected or paroxysmal which could account for the unexplained symptoms. Holter monitoring or electrophysiological studies are required to detect the paroxysmal atrial fibrillation.

In the current study the height of p wave on ECG was increased significantly after the right pneumonectomy but the increase was not significant after the left pneumonectomy. The increase of the atrial pressure after right pneumonectomy could explain the increased height of p waves after right pneumonectomy. Another finding supporting this situation was the detection of the findings of right ventricular hypertrophy after the first and years of right pneumonectomy. The systolic pulmonary pressures of these cases were recorded higher on preoperative echocardiography than postoperative echocardiography. The most likely explanation for this increase could be decrease in pulmonary vascular bed and subsequent increase of vascular resistance. However, the study could not validate this theory because either hemodynamic studies or cardiac magnetic resonance imaging was not performed. In contrast to the findings of patients with right pneumonectomy there was no statistical difference in systolic pulmonary artery pressures or right ventricular dimensions before and after the operation. These findings were consistent with the results of Foruolis et al. [13] but neither study had the hemodynamic data that could account for the differences of pulmonary artery pressures before and after pneumonectomy.

Several strengths and limitations of this study need to be acknowledged. First strength is the wide number of sample population. Moreover, in this study the changes of the heart after pneumonectomy were analyzed by combination of thorax CT, ECG, and echocardiography. However, there were some significant restrictions. First, this study was observational in design. Second limitation was that the follow-up duration was limited by two years. At the end, the authors hope that this study will be a call for future randomized controlled studies.

Conclusions

The current study showed that many significant changes occurred in the electrocardiographic and echocardiographic parameters of the heart after pneumonectomy. A clinician should be aware of these changes and their possible consequences. Possible cardiac arrhythmias could be the reason for the unexplained resting and exertional dyspnea besides decreased

pulmonary capacity. Pulmonary hypertension and increased workload of the right heart especially after right pneumonectomy may cause right heart failure. Multidisciplinary approach is necessary to provide best diagnostic and therapeutic strategy to these patients.

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Ethical statement: *The study was approved by the Local Ethics Committee of University (Date and decision no: 2019/1660), and written informed consent was obtained from each subject.*

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