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***Original Article** / Özgün Makale*

Electrocardiographic changes in primary spontaneous pneumothorax

Primer spontan pnömotoraksta elektrokardiyografik değişiklikler

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Background: This study aims to evaluate the electrocardiographic (ECG) changes in patients with primary spontaneous pneumothorax.

Methods: A total of 48 patients (42 males, 6 females; mean age 29.7±12.5 years, range 15 to 58 years) with PSP were prospectively analyzed between November 2010 and November 2011. Pneumothorax size was calculated using the Rhea method. At least two standard 12-lead ECG were obtained for each patient (after the diagnosis of pneumothorax and prior to drain placement - $ECG_{pneumothorax}$, and after a complete re-expansion of the lung was achieved and confirmed radiologically - $ECG_{re\text{-}expanded}$). P wave measurement, PR distance, QRS distance, QT interval and QT interval corrected for heart rate (QTc) were calculated. Heart rate (bpm), axis deviation measurement and the QRS amplitudes (QRSV1-6) in precordial leads were calculated.

Results: There were 29 cases (60.4%) of left-sided and 19 cases (39.6%) of right-sided pneumothorax. The mean relative volume of pneumothorax was 43.0±21.5%. The most common symptoms included chest pain in 34 patients (70.8%) and dyspnea in 14 patients (29.2%). The pneumothorax duration was ≤24 hours in 30 patients (62.5%) and >24 hours in 18 patients (37.5%). There was a statistically significant difference between before and after the treatment for QT duration, axis deviation, heart rate, QRSV1, QRSV4, QRSV5 and QRSV6 (respectively; p=0.001, p=0.023, p=0.001, p=0.010, p=0.046, p=0.000, p=0.008). A total of seven patients had relevant QRS abnormalities including incomplete right bundle branch block in three patients, ST elevation in two patients and T-wave pointedness in one patient.

Conclusion: Our study results suggest that left and right lung pneumothorax may cause axis variation, which is more pronounced in women, and that voltage increases after drainage in QRSV 4, 5 and 6 leads. In addition, pneumothorax may lead to specific ECG variations such as right bundle branch block and ST variations.

Keywords: Electrocardiography; pneumothorax; right bundle branch block.

Amaç: Bu çalışmada primer spontan pnömotoraks olgularındaki elektrokardiyografik (EKG) değişiklikler değerlendirildi.

Çalışma planı: Primer spontan pnömotorakslı toplam 48 hasta (42 erkek, 6 kadın; ort. yaş: 29.7±12.5 yıl; dağılım 15-58 yıl) Kasım 2010 - Kasım 2011 tarihleri arasında prospektif olarak incelendi. Pnömotoraks alanı Rhea metodu ile hesaplandı. Her hastaya en az iki kere standart 12 derivasyonlu EKG çekildi (pnömotoraks tanısından sonra ve göğüs tüpü uygulamasından önce - $EKG_{pnömotoraks}$ ve akciğerin yeniden ekspanse olması ve radyolojik olarak doğrulanmasından sonra - $EKG_{re\text{-}ekspanse}$). P dalgası ölçümü, PR mesafesi, QRS mesafesi, QT intervali ve kalp hızı için düzeltilmiş QT aralığı (QTc) hesaplandı. Ayrıca kalp hızı (dakikada nabız sayısı), aks deviasyonu ölçümleri ve prekordial derivasyonlarda QRS amplitüdleri (QRSV1-6) hesaplandı.

Bulgular: Pnömotoraks hastaların 29'unda (%60.4) sol, 19'unda (%39.6) sağ hemitoraksta idi. Pnömotoraks alanının ortalaması %43.0±21.5 idi. En sık görülen semptomlar, 34 hastada (%70.8) göğüs ağrısı, 14 hastada (%29.2) nefes darlığı idi. Pnömotoraks süresi 30 hastada (%62.5) ≤24 saat iken, 18 hastada (%37.5) >24 saat idi. Tedavi öncesi ve tedavi sonrası QT süresi, aks deviasyonu, kalp hızı, QRSV1, QRSV4, QRSV5 ve QRSV6 değerleri arasında istatistiksel olarak anlamlı bir fark saptandı (sırası ile p=0.001, p=0.023, p=0.001, p=0.010, p=0.046, p=0.000, p=0.008). Üç hastada sağ dal bloku, iki hastada ST yükselmesi ve bir hastada T dalgası sivriliği olmak üzere toplam yedi hastada ilişkili QRS anormallikleri saptandı.

Sonuç: Çalışma bulgularımız hem sağ hem de sol pnömotoraksın kadınlarda daha belirgin olmak üzere, aks değişikliğine neden olabileceğini ve QRSV 4, 5 ve 6 derivasyonlarında voltajın drenaj sonu arttığını göstermektedir. Ayrıca pnömotoraks sağ dal bloku ve ST değişikliği gibi özellikli EKG değişikliklerine de yol açabilir.

Anahtar sözcükler: Elektrokardiyografi, pnömotoraks; sağ dal bloku.

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A pneumothorax is the accumulation of free air between the visceral and parietal pleura. It can be caused by a variety of factors and is sometimes followed by the secondary development of lung collapse. In addition, a pneumothorax may occur spontaneously or be acquired. A primary spontaneous pneumothorax (PSP) may be defined as a pneumothorax that develops in patients with no history of lung disease through the perforation of the subpleural blebs. Leading to sudden chest pains and dyspnea.[1] The most important procedure in the diagnosis of a PSP is the posterior-anterior chest X-ray, but under certain circumstances, the similar symptomatology of a spontaneous pneumothorax and cardiac conditions (chest pain and dyspnea) together with electrocardiographic (ECG) abnormalities may lead to misdiagnosis and a delay in the treatment of a pneumothorax.[2]

There is no research showing the variations and frequencies of ECG abnormalities associated with a pneumothorax. Isolated case studies have been published, and these have usually focused on myocardial ischemia, myocardial infarction, pulmonary embolisms, and respiratory ECG amplitude variations.[3-8] Krenke et al.[2] performed the most in-depth research on both primary and secondary pneumothorax cases, and Rivas de Andrés et al.[9] determined that a secondary pneumothorax developed spontaneously in a patient with a history of lung disease [i.e., chronic obstructive pulmonary disease (COPD) or emphysema]. In these cases, the chronic lung disease also affected the heart, and more frequent variations in the ECG patterns were seen. For this reason, we wanted to analyze a large and relatively homogenous group, so our scope was limited to PSP patients. Moreover, we did not come across any previous literature that had tackled this issue.

Therefore, in this prospective study, we tried to identify how ECG variations occur in PSP cases and determine the relationship between these variations and the pneumothorax volume along with the body side, age, gender, and symptoms of the patient.

PATIENTS AND METHODS

This prospective study focused on patients who were diagnosed with PSP based on their histories, physical examinations, and chest X-rays between November 2010 and November 2011. Patients with a tension pneumothorax and those for whom lung re-expansion had failed were excluded. The study group ultimately consisted of 48 patients (42 males, 6 females; mean ages 29.7±12.5 years; range 15 to 58 years) who were diagnosed with a pneumothorax and who underwent an ECG prior to drain placement ($ECG_{pneumothorax}$). As the lung re-expanded, the chest tube was removed. After the X-ray confirmed the re-expansion, the ECG was then repeated ($ECG_{re\text{-}expanded}$). The following data were recorded for each patient: age, gender, dominant symptoms (chest pain or dyspnea), pneumothorax volume, pneumothorax duration (the time between the beginning of the symptoms and the admission of the patient to the hospital along with the subsequent diagnosis of the pneumothorax), and pneumothorax side. We also calculated the P wave measurement, PR distance, QRS distance, QT interval, and QT corrected by heart rate (QTc) using the ECG measurements. Furthermore, the heart rate (per minute), axis deviation (Ax) measurement in degrees, and the QRS amplitudes (QRSV1-6) in the precordial derivations were also determined. In order to identify whether the pneumothorax led to the ECG variations, the $ECG_{pneumothorax}$ and $ECG_{re\text{-}expanded}$ were compared, and the pneumothorax volumes were calculated using the Rhea method.[10] The patients were then divided into two groups according to pneumothorax duration, with one group composed of those who came to the hospital with a duration of 24 hours or less and those with a duration of more than 24 hours. We also examined the ECG variations and whether or not they were affected by pneumothorax volume, gender, dominant symptom, pneumothorax side, and pneumothorax duration.

The patients in the study underwent the standard 12-lead ECG procedure (25 mm/s, 10 mm/mV) while resting, and the measurements were recorded manually using a 3x magnifier and protractors by an expert cardiologist who was blinded to the patient information,. The P wave measurement was taken at the beginning and end of the P wave while the QRS distance was calculated between the start of the Q wave and end of the S period in derivations II and V1 because they yielded the clearest results. In addition, the QT interval was calculated from the start of the Q wave to the end of the T wave (the point where it reached the T-P line). In addition, when the U wave was present, the deepest point of the curve between the T and U waves was used. In derivations where the end of the T wave was not visible, the data was not recorded. Furthermore, we utilized Bazett's formula to calculate the QTc.[11] The QT intervals were based on at least seven derivations, three of which being precordial, and these was measured manually as well as with the aid of a computer. In manual measurements, it is difficult to determine exactly where the T wave ends; hence the QT interval has a high error rate. However, it has been shown that automatic measurements also yield erroneous results and are not superior to manual ones.[12,13] In our study, the Ax measurements were calculated conventionally by marking the QRS vectors on the ECG readout, which benefitted from the DI and aVF derivations. We also calculated the average vectors. In order for the QRS amplitude variation to be sound, care was taken to ensure that the electrodes were attached to exactly the same places before and after the precordial derivations (V1-6). Furthermore, the QRS amplitude was identified by extracting the S amplitude value in millimeters from the R amplitude value.

Statistical analysis

For data analysis, the IBM SPSS Statistics version 19.0 for Windows software program (IBM, Armonk, NY, USA) was used. The quantitative data was analyzed in terms of adaptability to the bell curve distribution form using the Kolmogrov-Smirnov test. The data that was not adaptable to a normal distribution was analyzed using nonparametric methods, whereas parametric methods were used to analyze the data that was normally distributed. When comparing the independent groups, an independent t-test and the Mann-Whitney U test were used, whereas the dependent groups were compared using the Wilcoxon signed-rank test. For multiple group comparisons, repeated-measure analysis of variance (ANOVA) tests were used, and to examine the relationships between the variables, Kendall's tau-b and Pearson's correlation tests were employed. For quantitative data, the mean, standard deviation, and minimum and maximum values were calculated and shown in the tables. In addition, number (n) and percentage (%) were used for the categorical variables. All data was analyzed using a 95% confidence interval (CI), and p values of <0.05 were considered to be significant.

RESULTS

The mean age for the women (29.6±13.1 years) in the study and the mean age for men (30.3±7.4 years) were not significantly different (p=0.901). In terms of the dominant symptom, 34 (70.8%) of the patients reported chest pain while 14 (29.2%) suffered from dyspnea. Twenty-nine (60.4%) of the patients had a pneumothorax in the left lung while it was in the right lung for 19 (39.6%) of the study participants. In 30 patients (62.5%), the pneumothorax duration was under 24 hours or less, whereas the duration was over 24 hours for 18 (37.5%). Furthermore, the mean of the pneumothorax volume for all of the participants was 43.0±21.5% while the median was 42.6, and the minimum and maximum values were 12.6% and 92.4% respectively. Moreover, the pneumothorax volume did not vary significantly by gender (male vs. female), dominant symptom (chest pain vs. dyspnea), pneumothorax side (left vs. right), or pneumothorax duration (≤24 hours vs. >24 hours) (Table 1).

The $ECG_{pneumothorax}$ and $ECG_{re\text{-}expanded}$ variables for each case were also compared, and there was no significant difference between the mean and median values before and after the treatment for P, PR, QRS, and QTc duration and the QRS amplitude at V2 and V3 (p>0.05). However, there was a significant difference between the mean and median values before and after the treatment with regard to QT duration, Ax, heart rate, and QRS amplitude at V1, V4, V5, and V6 (p<0.05) (Table 2).

For the $ECG_{pneumothorax}$ and $ECG_{re\text{-}expanded}$ variables examined in the left-lung pneumothorax, there was a significant difference between the mean and median values before and after the treatment for QT, heart rate, and QRS amplitude at V4, V5, and V6 (p<0.05), but for the QT and QRS amplitude at V4, V5, and V6, the mean and median values were significantly lower at the post-treatment stage. Additionally, the heart rate pre-treatment measurements were significantly higher than the post-treatment measurements.

For the $ECG_{pneumothorax}$ and $ECG_{re\text{-}expanded}$ variables examined in the right-lung pneumothorax, a significant difference was noted between the mean and median values before and after the treatment for QT, heart rate, and QRS amplitude at V1 and V5 (p<0.05). For the QT and QRSV5 amplitude variables, the mean and median values were significantly lower at the pre-treatment stage, and the post-treatment measurements for the QRS amplitude at V1 and the heart rate values were significantly higher than for the pre-treatment measurements. The relationship between the ECG

Table 1. Comparison of the pneumothorax volume by gender, complaint, side, and duration

	n	Mean±SD	Median	*p**
Sex				
Male	42	42.1±22.2	39.6	0.318
Female	6	49.0±16.2	49.3	
Symptom				
Chest pain	34	39.4±22.1	36.1	0.051
Dyspnea	14	51.7±17.5	48.7	
Pneumothorax side				
Left	29	39.4±22.1	36.1	0.210
Right	19	51.7±17.5	48.7	
Pneumothorax duration				
≤24 hours	30	45.3±23.4	43.5	0.509
>24 hours	18	39.1±17.7	37.2	

Mann-Whitney U Test; SD: Standard deviation; * Non-significant.

Table 2. Comparison of the ECG variations in the pre- and post-treatments of all of the left- and right-lung pneumothorax cases

	Total patients (n=48)			Left pneumothorax (n=29)			Right pneumothorax (n=19)		
ECG	Mean±SD	Median	*p*	Mean±SD	Median	*p*	Mean±SD	Median	*p*
$P_{pneumothorax}$	100±22.7	100	0.103*	103.5±19.5	120	0.114*	94.7±26.5	80	0.578*
$P_{re\text{-}expanded}$	103.5±24.2	120		108.6±2	120		95.8±27.1	80	
$PR_{pneumothorax}$	143.3±22.3	160	0.159*	147.6±22.9	160	0.101*	136.8±20.3	120	1*
$PR_{re\text{-}expanded}$	147.1±23.2	160		153.8±22.7	160		136.8±20.3	120	
$QRS_{pneumothorax}$	88.8±18.4	80	0.129*	87.6±17.3	80	0.414*	90.5±20.4	80	0.180*
$QRS_{re\text{-}expanded}$	90.4±18.3	80		88.6±16.0	80		93.2±21.6	80	
$QT_{pneumothorax}$	332.9±26.9	320	0.001	333.8±28.8	320	0.022	331.6±24.3	320	0.009
$QT_{re\text{-}expanded}$	349.4±29.3	360		348.9±33.6	360		350±21.9	360	
$Ax_{pneumothorax}$	67.3±30.4	68	0.023	62.2±28.1	70	0.098*	75.1±32.9	65	0.440*
$Ax_{re\text{-}expanded}$	61.04±28.2	60.5		55.2±29.4	55		69.9±24.3	70	
$HR_{pneumothorax}$	83.5±16.6	75	0.001	85.7±16.9	76	0.038	80.2±16.0	75	0.014
$HR_{re\text{-}expanded}$	75.4±11.7	74		78.2±12.5	75		71.1±9.0	72	
$QTc_{pneumothorax}$	388.9±33.9	391	0.935*	394.7±33.0	397	0.901*	380.2±34.3	363	0.969*
$QTc_{re\text{-}expanded}$	389.4±37.9	395.5		395.7±40.7	398		379.8±31.9	383	
$QRSV1_{pneumothorax}$	-5.5±4.2	-5	0.010	-6.25±4.3	-6	0.431*	-4.3±3.8	-5	0.004
$QRSV1_{re\text{-}expanded}$	-6.625±3.9	-6		-6.8±3.6	-6		-6.4±4.5	-6	
$QRSV2_{pneumothorax}$	-6±4.5	-6	0.649*	-5.9±4.2	-6	0.172*	-6.1±5.0	-6.5	0.503*
$QRSV2_{re\text{-}expanded}$	-5.7±5.2	-6		-4.8±4.7	-4		-7.1±5.8	-7	
$QRSV3_{pneumothorax}$	-6.8±6.4	-7	0.084*	-6±6.8	-5	0.211*	-7.9±5.9	-8	0.246*
$QRSV3_{re\text{-}expanded}$	-5.1±6.1	-6		-4.4±5.8	-5		-6.2±6.6	-8	
$QRSV4_{pneumothorax}$	2.1±6.4	0	0.046	1.6±6.4	0	0.010	2.9±6.6	6	0.960*
$QRSV4_{re\text{-}expanded}$	4.8±7.4	6.5		6.1±6.8	7		2.8±8.1	6	
$QRSV5_{pneumothorax}$	4.9±6.7	3	0.000	3.5±6.7	2	0.000	6.9±6.2	9	0.043
$QRSV5_{re\text{-}expanded}$	10.5±6.1	10		10.3±6.5	10		10.9±5.6	11	
$QRSV6_{pneumothorax}$	7.3±5.6	7	0.008	5.4±5.2	4	0.003	10.2±4.9	9	0.524*
$QRSV6_{re\text{-}expanded}$	9.8±5.3	9		8.9±5.1	9		11.1±5.4	9	

Paired t test, Wilcoxon Signed Ranks Test; ECG: Electrocardiography; SD: Standard deviation; * Non-significant; HR: Heart rate.

variables and QRS amplitude at V4 and V6 before and after treatment of the left-lung pneumothorax and the relationship between QRSV1 amplitude and the right-lung pneumothorax are displayed in Table 2.

We also compared the $ECG_{pneumothorax}$ and $ECG_{re\text{-}expanded}$ axis variable according to gender, and a statistically significant association was found (p=0.030). For women, the $Ax_{pneumothorax}$ results (mean±SD 75±6.6; median 77.5) were significantly different from the $Ax_{re\text{-}expanded}$ results (mean±SD, 48.7±10.0; median 50), with the $Ax_{pneumothorax}$ results being significantly higher (p=0.028). An examination of Figure 1 by gender shows that the results confirm this analysis. For the men, the pre-treatment $Ax_{pneumothorax}$ values were smaller that the $Ax_{re\text{-}expanded}$ values, but this decrease was not statistically significant. However, there was a more dramatic decrease in the female patient group that was statistically significant. Furthermore, a comparison of heart rate values by gender did not yield statistically significant results (p=0.802), and a comparison of pre-treatment and post-treatment QRSV1, V4, V5 and V6 amplitude results revealed no statistically significant relationship, with the exception of QRSV5 (Table 3).

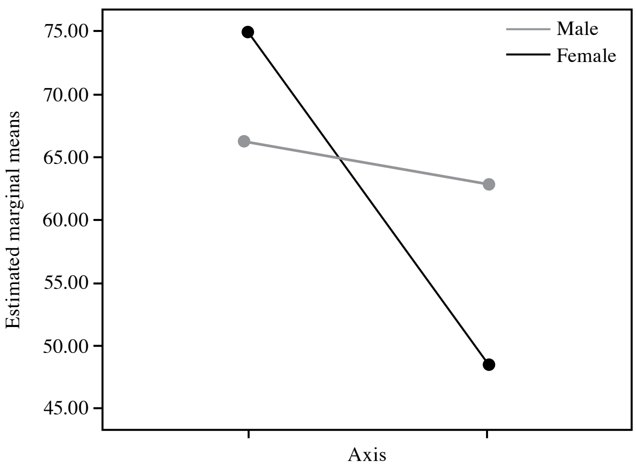

Figure 1. The effect of gender on axis.

Table 3. Gender comparison in the electrocardiography variables of the pre- and post-treatment values

	Male (n=6)			Female (n=6)			
	Mean±SD	Median	*p*	Mean±SD	Median	*p*	*p*
$QT_{pneumothorax}$	334.8±4.4	320		320±0	320		0.172
$QT_{re\text{-}expanded}$	349.8±4.7	360		346.7±8.4	360		0.866
P (QT)			0.003			0.046	*0.495
$Ax_{pneumothorax}$	66.2±4.9	65.50		75±6.6	77.50		0.453
$Ax_{re\text{-}expanded}$	62.8±4.4	61.5		48.7±10.0	50		0.254
P (Ax)			0.358			0.028	*0.030
$HR_{pneumothorax}$	82.6±2.6	75		89.5±5.0	92		0.143
$HR_{re\text{-}expanded}$	74.6±1.7	74		81.2±6.7	81.5		0.433
P (HR)			0.006			0.043	*0.802
$QRSV1_{pneumothorax}$	-5.6±0.7	-5		-4.2±1.2	-4.5		0.336
$QRSV1_{re\text{-}expanded}$	-6.8±0.6	-6		-5.7±0.8	-5.5		0.338
P (QRSV1)			0.030			0.066	*0.851
$QRSV4_{pneumothorax}$	1.9±1.0	0		3.7±1.8	3		0.390
$QRSV4_{re\text{-}expanded}$	4.8±1.2	7		4.8±1.2	5.5		0.628
P (QRSV4)			0.056			0.674	*0.972
$QRSV5_{pneumothorax}$	4.5±1.1	3		7.2±2.2	7.5		0.257
$QRSV5_{re\text{-}expanded}$	10.7±1.0	10.5		9±2.5	8.5		0.524
P (QRSV5)			0.000			0.400	*0.022
$QRSV6_{pneumothorax}$	6.9±0.8	7		9.8±3.0	9.5		0.276
$QRSV6_{re\text{-}expanded}$	9.6±0.8	9		11.3±2.9	9		0.754
P (QRSV6)			0.010			0.345	*0.664

Box's Test >0.05 - General Linear Model (Repeated Measures); SD: Standard deviation; * General *p* value.

We also compared QT, axis, heart rate, QRSV1, V4, V5, and V6 amplitude values between the $ECG_{pneumothorax}$ and $ECG_{re\text{-}expanded}$ and found no statistically significant relationship.

Moreover, pre- and post-treatment comparisons of QT, axis, heart rate, QRSV1, V4, V5, and V6 amplitude values of the pneumothorax side yielded no statistically significant associations, and no definite relationship was found between the pneumothorax sides with respect to axis. However, for the left-lung pneumothorax, an average inclination of 15 degrees to the horizontal position was identified while it was 5 degrees to the vertical position for the right-lung pneumothorax (Table 2).

When we compared the pneumothorax duration of the QT, axis, heart rate, QRSV1, V4, V5, and V6 amplitude values for the $ECG_{pneumothorax}$ and $ECG_{re\text{-}expanded}$, we determined that there was no statistically significant correlation (Table 4).

(Figures 2, 3, and 4) Seven of the patients featured ECG changes. Three cases were observed to have a right bundle branch block on the $ECG_{pneumothorax}$ (two with a left-lung pneumothorax and one with a right-lung pneumothorax). In addition, ST elevation was identified in two cases while T elevation was identified in one case and coronary sinus rhythm in another. After the re-expansion of the lung, all of the ECG variations went into remission (Table 5).

DISCUSSION

Acute chest conditions, such as myocardial infarction, pulmonary embolisms, and pneumothoraces, have a fairly common symptomatology, with chest pain and dyspnea being the dominant manifestations in various dissimilar conditions. One of the most important diagnostic tools used in the differential diagnosis of these conditions is ECG. Although this usually reveals cardiac problems, electrolyte imbalances, acute central nervous system events, hypo- and hyperthermia, some medications and stimulants may cause ECG variations. Additionally, a pneumothorax has also been identified as one of the rare conditions that create ECG variations.[8,14,15]

The literature lacks a study with a wide enough scope to identify the ECG variations and frequency with regard to a spontaneous pneumothorax, with the study by Krenke et al.,[2] which was comprised of 40 patients, being the largest sample group. Their research focused on primary and secondary spontaneous

Table 4. Comparison of pneumothorax duration with regard to the electrocardiography variables of the pre- and post-treatment values

	Pneumothorax duration						
	≤24 hours			>24 hours			
	Mean±SD	Median	*p*	Mean±SD	Median	*p*	*p*
$QT_{pneumothorax}$	331.3±5.6	320		335.56±4.7	320		0.473
$QT_{re\text{-}expanded}$	350.7±6.0	360		347.2±5.5	360		0.782
P (Pneumothorax duration)			0.005			0.065	*0.737
$Ax_{pneumothorax}$	71.9±5.5	68		59.6±7.0	66		0.337
$Ax_{re\text{-}expanded}$	66.8±4.9	62.5		51.4±6.6	48.50		0.067
P (Pneumothorax duration)			0.147			0.299	*0.967
$HR_{pneumothorax}$	83.5±2.8	75		83.4±4.5	75		0.846
$HR_{re\text{-}expanded}$	75.4±2.2	75		75.4±2.8	72		0.995
P (Pneumothorax duration)			0.012			0.062	*0.759
$QRSV1_{pneumothorax}$	-5.7±0.7	-5		-5±1.1	-5		0.965
$QRSV1_{re\text{-}expanded}$	-6.7±0.6	-6		-6.6±1.1	-6.5		0.568
P (Pneumothorax duration)			0.134			0.028	*0.582
$QRSV4_{pneumothorax}$	2.8±1.2	5.5		1.1±1.4	-0.5		0.395
$QRSV4_{re\text{-}expanded}$	5.4±1.2			3.9±2.0	5.5		0.436
P (Pneumothorax duration)			0.093			0.274	*0.977
$QRSV5_{pneumothorax}$	4.8±1.4	4		4.9±1.3	3		0.974
$QRSV5_{re\text{-}expanded}$	10.5±1.1	10		10.5±1.6	10.5		0.999
P (Pneumothorax duration)			0.000			0.002	*0.373
$QRSV6_{pneumothorax}$	7.5±1.1	7.5		7±1.3	7		0.786
$QRSV6_{re\text{-}expanded}$	9.1±0.8	9		10.9±1.5	10		0.494
P (Pneumothorax duration)			0.072			0.053	*0.945

Box's Test >0.05 - General Linear Model (Repeated Measures); SD: Standard deviation; * General *p* value.

pneumothorax cases, and they determined that PSP occur in young people without any additional lung disease. In contrast to the Krenke study, ours included only PSP cases because we wanted to have a more homogenous group of patients.

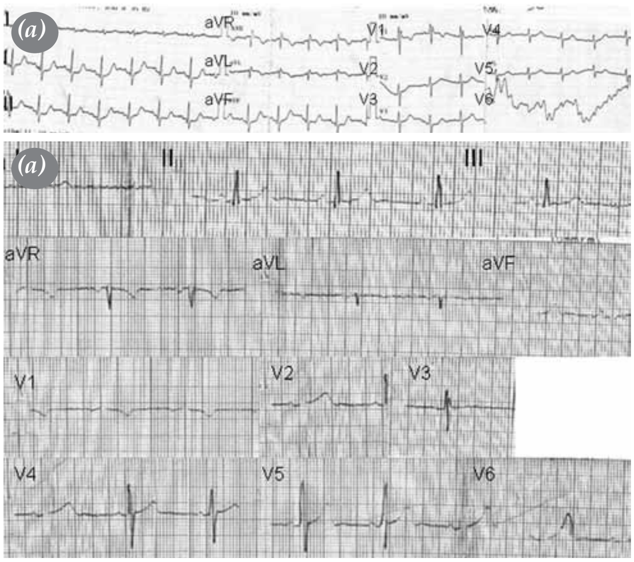

Figure 2. (a) Right bundle branch block in a 46-year-old male with a left-sided pneumothorax as seen on ECG at admission; **(b)** Electrocardiographic after lung re-expansion.

A pneumothorax is known to cause changes in heart position as well as secondary cardiac axis variations. In a study involving 43 patients with a pneumothorax caused by tuberculosis. Armen and Frank[15] observed that both left- and right-lung pneumothoraces lead to right axis inclination, with this variation being observed in nearly 40% of their cases. Abnormal left axis deviation is more frequently caused by a left-lung pneumothorax while abnormal right axis deviation is usually caused by a right-lung pneumothorax due to the instantaneous stresses placed upon the right ventricle along with a widening of this heart chamber.[16,17] Walston et al.[18] reported that in seven left-lung pneumothorax cases, a right axis inclination of between 11° and 235° was observed. In our study, a statistically significant difference was identified between the pre- and post-treatment axis values; however, no relationship was found between the side on which the pneumothorax occurred and the axis measurement, even though we observed that in cases involving a left-lung pneumothorax, there was an average horizontal

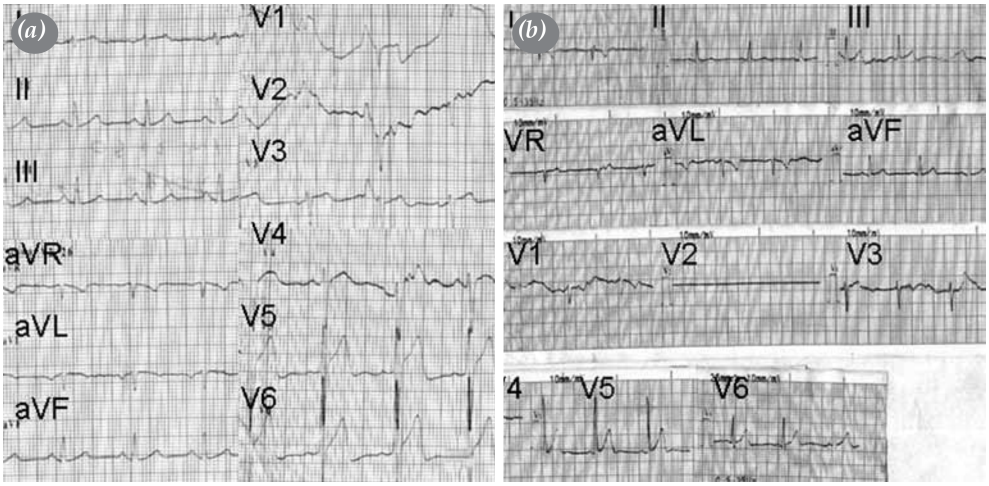

Figure 3. (a) ST elevation in a 34-year-old-male with a right-sided pneumothorax as seen on electrocardiographic at admission; **(b)** Electrocardiographic after lung re-expansion.

inclination of 15º and an average vertical inclination of 5º in the patients with a right-lung pneumothorax. In addition, when we compared gender and axis values, this deviation occurred more frequently in women. Furthermore, we also determined that there was no relationship between the pneumothorax durations, sides, and area and the axis changes in the female patients.

As stated by Walston et al.,[18] abnormal myocardial repolarization due to abnormal myocardial perfusion, intrapleural and/or pericardial cavity pressure variations, and increased pulmonary circulation resistance may lead to T variations as well as voltage changes and increased deviation in the QT interval. In our study, the $QT_{pneumothorax}$ values were lower than the $QT_{re\text{-}expanded}$ values while the heart rate during the pneumothorax was elevated. This can occur due to tachycardia and may be caused by sympathetic activation, pain, shortness of breath during exercise, or lung hypoxia. Related to this, the QT duration was shorter in our study. The fact that we found no differences between the corrected QT values leads us to consider the possibility that this situation was caused by an elevated heart rate.

Echocardiography variations due to a pneumothorax were observed in both left- and right- lung pneumothoraces in our study, but there were different effects depending on the side of the pneumothorax . It is highly probable that the QRS amplitude variations were caused by changes in the distance between the heart and chest wall, which were secondary to the changes that took place in electrical impulse transmission paths. Since the air preventing the transmission between the heart and

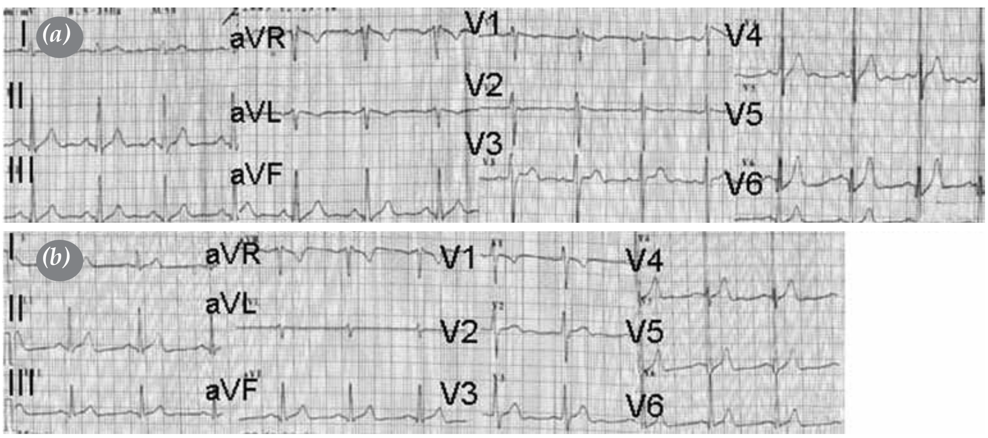

Figure 4. (a) T elevation a 16-year-old male with a left-sided pneumothorax as seen on electrocardiographic at admission; **(b)** Electrocardiographic after lung re-expansion.

Table 5. Characteristics of the seven patients according to electrocardiography changes

Patients no	Age/gender	Side	Symptom	Pneumothorax size (%)	The changes in ECG	$Ax_{re\text{-}expanded}$	$Ax_{pneumothorax}$
1	26/M	R	Chest pain	20.13	Right bundle branch block	110°	140°
2	46/M	L	Chest pain	26.44	Right bundle branch block	75°	90°
3	31/M	L	Chest pain	64.09	Right bundle branch block	75°	55°
4	58/M	R	Dyspnea	23.24	Coronary sinus arrhythmia	127°	90°
5	34/M	R	Chest pain	77.68	ST (V5-6) 2 mm elevated	110°	90°
6	17/M	L	Chest pain	46.79	ST (V3-4) 1 mm elevated	50°	77°
7	16/M	L	Chest pain	17.05	T (V5-6) pointedness	73°	75°

ECG: Electrocardiography; R: Right; L: Left.

chest wall was eradicated after the treatment, the left derivations, V4, V5, and V6 had much higher QRS amplitudes. In addition, we identified that the significance of the pre- and post-treatment differences in the QRSV4 and QRSV6 amplitudes was related to the left-lung pneumothorax while the change in the QRSV1 amplitude was associated with the right-lung pneumothorax. It is probable that the voltage value for V1 for right-sided derivations of the right-lung pneumothorax cases varied since the air preventing the transmission was eradicated after the treatment. We can also speculate that in the left chest derivations, the significant increase in V4 amplitude (2.15 mm vs. 4.83 mm), V5 amplitude (4.85 mm vs. 10.50 mm), and V6 amplitude (7.30 mm vs. 9.79 mm) was caused by the eradication of the air that was preventing transmission after drainage as well as the volume and pressure loads caused by pulmonary circulation along with the increase in venous circulation. It can also be postulated that the change in the heart axis also contributed to this situation.

In the literature, it has been reported that branch blocks occur in pneumothorax patients.[8] Two mechanisms may play a role in those cases. Air accumulating in the right pleural cavity may increase the pressure on the right ventricle, and the increased pulmonary artery pressure (PAP) may cause abnormalities in the heart transmission system. We also believe that the right branch blocks in three of our patients as well as the other variations in our study participants were caused by complex mechanisms.

Conclusion

We identified that left- and right-lung pneumothoraces cause axis variation and that this is more pronounced in women. In addition, we determined that the voltage increases after drainage in QRSV 4, 5, and 6 derivations and specific ECG variations such as those involving right branch blocks and the ST. However, more research is needed to identify the pathophysiological mechanisms associated with these variations.

Declaration of conflicting interests

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