Review

ANNALS OF MEDICINE & SURGERY

OPEN

Electrocardiographic changes in pneumothorax: an updated review

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Abstract

ECG changes in pneumothorax have gained recognition as important indicators of cardiopulmonary interactions. This narrative review examines the existing literature to provide insights into the various ECG abnormalities observed in patients with pneumothorax, their underlying mechanisms, and clinical implications. The review highlights the commonly reported changes, including alterations in the electrical axis, ST segment deviations, T-wave abnormalities, and arrhythmias. The rightward shift of the electrical axis is attributed to cardiac displacement caused by increased intrathoracic pressure. ST segment deviations may reflect the influence of altered intrathoracic pressure on myocardial oxygen supply and demand. T-wave abnormalities may result from altered myocardial repolarization and hypoxemia. Arrhythmias, although varying in incidence and type, have been associated with pneumothorax. The clinical implications of these ECG changes are discussed, emphasizing their role in diagnosis, risk stratification, treatment optimization, and prognostication. Additionally, future research directions are outlined, including prospective studies, mechanistic investigations, and the integration of artificial intelligence. Enhancing our understanding of ECG changes in pneumothorax can lead to improved patient care, better management strategies, and the development of evidence-based guidelines. The objective of this review is to demonstrate the presence of various ECG abnormalities in patients with pneumothorax.

Keywords: arrhythmia, coronary artery disease, ischemia, pericardial effusion, p-wave

Introduction

Pneumothorax, the presence of air in the pleural cavity, is a potentially life-threatening condition that can cause significant respiratory compromise[1]. While the primary focus of diagnosing and managing pneumothorax revolves around respiratory symptoms and radiological findings, recent studies have shed light on the impact of pneumothorax on cardiac function[2]. ECG changes in pneumothorax have emerged as an intriguing area of investigation, highlighting the intricate interplay between the heart and lungs[3]. The ECG is a valuable diagnostic tool routinely used to assess myocardial electrical activity and detect cardiac abnormalities[4]. Traditionally, its primary application has been in diagnosing and managing various cardiac conditions, such as myocardial infarction, arrhythmias, and conduction disturbances[5]. However, researchers and clinicians have started recognizing that ECG findings can provide crucial insights into the pathophysiological consequences of extracardiac conditions, including pneumothorax. In pneumothorax, the accumulation of air in the pleural space causes lung collapse and compromises respiratory function. As a result, the altered intrathoracic pressure dynamics and lung mechanics can exert significant effects on cardiac performance[6]. The heart, situated within the thoracic cavity, is intimately connected to the lungs through anatomical and physiological interactions[7]. Changes in intrathoracic pressure due to pneumothorax can disrupt this delicate equilibrium, leading to direct or indirect effects on cardiac electrical

HIGHLIGHTS

- ECG changes in pneumothorax have gained recognition as important indicators of cardiopulmonary interactions.
- The rightward shift of the electrical axis is attributed to cardiac displacement caused by increased intrathoracic pressure.
- ST segment deviations may reflect the influence of altered intrathoracic pressure on myocardial oxygen supply and demand.
- T-wave abnormalities may result from altered myocardial repolarization and hypoxemia.
- Arrhythmias, although varying in incidence and type, have been associated with pneumothorax.

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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Annals of Medicine & Surgery (2024) 86:3551–3556

Received 31 August 2023; Accepted 9 April 2024

Published online 19 April 2024

http://dx.doi.org/10.1097/MS9.0000000000002080

conduction, myocardial oxygen supply, and overall hemodynamics[8]. Several studies have reported distinct ECG changes associated with pneumothorax[9–15]. These changes may manifest as alterations in the electrical axis, ST segment deviations, T-wave abnormalities, and even arrhythmias[9–15]. The underlying mechanisms of these ECG findings are multifactorial and complex, involving factors such as altered cardiac position, tension on pericardial structures, impaired ventricular filling, and decreased blood oxygenation[1].

Understanding the ECG changes associated with pneumothorax is not only important for accurate diagnosis but also for recognizing potential cardiac complications that may arise as a consequence of this respiratory disorder. Timely recognition of these ECG findings can prompt appropriate management strategies, including prompt treatment of the pneumothorax, optimization of respiratory support, and close monitoring of cardiac parameters. In this paper, we aim to provide a comprehensive overview of the various ECG changes observed in pneumothorax, exploring their potential mechanisms and clinical implications. By elucidating the connection between pneumothorax and its impact on cardiac electrical activity, we hope to enhance the understanding and awareness of this underrecognized aspect of pneumothorax management. Ultimately, such knowledge can contribute to improved patient outcomes and guide clinical decision-making in the context of this challenging clinical scenario.

Methods

For this narrative review, a comprehensive search of the existing literature was conducted to identify relevant studies and articles related to ECG changes in pneumothorax. Electronic databases including PubMed, MEDLINE, and Google Scholar were extensively searched, using keywords such as 'pneumothorax', 'tension pneumothorax', 'electrocardiogram', 'ECG changes', and 'cardiopulmonary interactions', 'hypoxia', and their variations. The search was limited to articles published in English and included studies from inception to September 2023. Initially, broad inclusion criteria were applied to capture a wide range of studies discussing ECG changes associated with pneumothorax. This included original research articles, case reports, observational studies, and reviews. After reviewing the titles and abstracts, studies that were deemed irrelevant or did not directly address the topic were excluded. The remaining articles were then subjected to a detailed full-text review to assess their eligibility for inclusion in this narrative review. Studies that provided substantial information on ECG changes in pneumothorax and their underlying mechanisms were selected. Additionally, references to the selected articles were reviewed to identify any additional relevant studies that may have been missed during the initial search.

Main findings

ECG changes in pneumothorax have gained recognition as an important aspect of cardiopulmonary interactions. The studies included in this narrative review provide valuable insights into the various ECG abnormalities observed in patients with pneumothorax, shedding light on the potential mechanisms and clinical implications of these changes. In this discussion section, we will delve deeper into the findings, examine the underlying pathophysiology, and explore the significance of ECG changes in the management of pneumothorax. Figure 1 shows a graphical abstract of ECG abnormalities after pneumothorax. Table 1 highlights studies with ECG changes observed in pneumothorax.

Electrical axis alterations

A significant number of studies reported alterations in the electrical axis in patients with pneumothorax[16–19]. The most commonly observed change was a rightward shift of the electrical axis. The underlying mechanism for this shift can be attributed to the displacement of the heart within the thoracic cavity due to increased intrathoracic pressure caused by the pneumothorax[1]. As the air accumulates in the pleural space, it leads to lung collapse and pushes the mediastinum, including the heart, toward the contralateral side[1]. This displacement affects the electrical vectors generated by the heart, resulting in a rightward deviation of the electrical axis on the ECG. The heart's electrical activity is typically represented by vectors, which are graphical representations of the direction and magnitude of the electrical impulses generated during the cardiac cycle. These vectors determine the electrical axis of the heart[1]. The normal electrical axis is directed towards the left side of the chest. However, when there is a significant displacement of the heart due to accumulated air in the pleural space, it alters the position and orientation of the heart within the chest cavity. This change in the heart's position can lead to a rightward deviation of the electrical axis on the ECG, which is a graphical representation of the heart's electrical activity. In simpler terms, the heart's electrical signals are now oriented more towards the right side of the chest due to the physical displacement caused by the accumulated air[1,2]. This rightward deviation of the electrical axis on the ECG can serve as an important clinical indicator and can help healthcare providers diagnose conditions such as tension pneumothorax, a medical emergency where air accumulation in the pleural space compresses the lung and shifts the mediastinum, leading to potentially life-threatening cardiovascular effects. In addition to the electrical axis deviation, a sizable pneumothorax can lead to ST-segment and T-wave changes on the ECG[13]. These changes may indicate myocardial strain or ischemia due to the altered positioning and

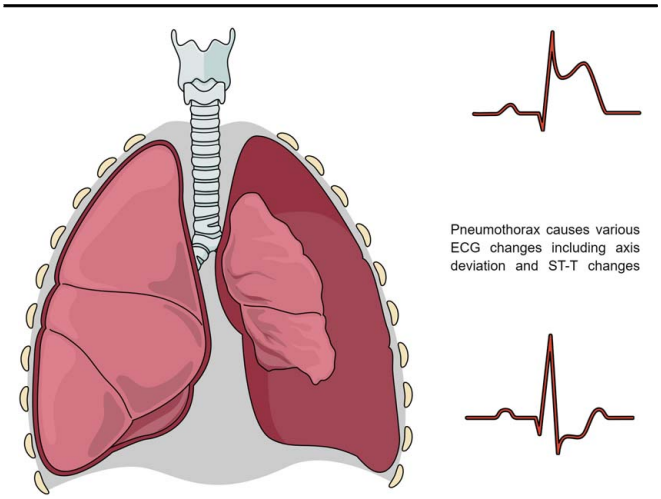

Figure 1. ECG changes in pneumothorax.

Table 1

Study characteristics

Author (Years) [ref]	Type of study	Main findings
Krenke (2008)[3]	Observational study	Significant ECG abnormalities were found in patients with spontaneous pneumothorax, with the most notable changes observed in cases of massive right-sided pneumothorax. Abnormalities included abnormal axis deviation, relevant QRS abnormalities, and changes in QRS amplitude
Feldman (1984)[9]	Case report	Bilateral pneumothoraces in a patient with anterior myocardial infarction resulted in differing ECG changes, with left pneumothorax causing reappearance of precordial R waves while right pneumothorax showed no ECG changes. This suggests the importance of air insulating the chest wall in influencing ECG alterations
Shiyovich (2011)[10]	Case report	Left-sided spontaneous pneumothorax in a young patient presented with ECG changes resembling acute myocardial infarction, including ST-segment elevations and T-wave inversions in precordial leads. These changes resolved after pneumothorax decompression. Possible mechanisms explaining the ECG findings were proposed
Strizik (1999)[11]	Case report	A case report highlighted new ECG changes associated with left tension pneumothorax, including PR-segment elevation in inferior leads and reciprocal PR-segment depression in the aVR lead, suggesting atrial injury and/or ischemia as the cause
Klin (2021)[13]	Observational study	ECG changes were observed in 21% of adolescents with primary spontaneous pneumothorax (PSP), including ST elevation, inverted T-wave, incomplete right bundle branch block, and others, with no correlation found between ECG changes and pneumothorax side/size
Khan (2023)[14]	Case report	A case study demonstrated ECG changes in a patient with sudden-onset chest pain and shortness of breath due to left-sided pneumothorax, including right axis deviation, diminished R waves, and small QRS complexes in precordial leads, resolving with pneumothorax resolution
Habibzadeh (1980)[15]	Case report	A patient with chronic obstructive pulmonary disease presented with 100% left-sided pneumothorax and marked ECG changes, emphasizing the importance of recognizing ECG manifestations to avoid delay in diagnosis and therapy
Ruhela (2018)[16]	Case report	The first case of acute-onset complete right bundle branch block (RBBB) due to left-sided pneumothorax in a young patient after blunt chest trauma was reported, with ECG findings reverting to normal after pneumothorax decompression. Possible mechanisms were discussed
Scott Weitiers (2014)[17]	Case report	A case report highlighted an ECG finding resembling limb lead reversal in a patient with tension pneumothorax, suggesting clinical suspicion for spontaneous pneumothorax when encountering such ECG abnormalities despite correct lead placement

compression of the heart. These ECG changes can be seen as inverted T-waves, ST-segment depression, or elevation, depending on the specific effects on the heart's blood supply. A large pneumothorax can also cause mechanical irritation to the heart and its surrounding structures. This irritation can lead to the development of arrhythmias, abnormal heart rhythms[19]. These arrhythmias may be reflected in the ECG as irregular rhythms, such as atrial fibrillation or ventricular arrhythmias. In severe cases of pneumothorax, particularly tension pneumothorax, there can be significant hemodynamic consequences. Increased pressure within the pleural space can compress the great vessels (such as the superior vena cava) and impair venous return to the heart, leading to decreased cardiac output[1]. This can manifest as low blood pressure, reduced pulse pressure, and signs of shock. These hemodynamic changes can also be detected on the ECG as signs of reduced cardiac output and tissue perfusion.

ST segment deviations

ST segment deviations, including ST elevation or depression, were frequently reported in the studies included in this review[18,19]. The presence of ST segment changes may reflect the influence of altered intrathoracic pressure on myocardial oxygen supply and demand[20]. The increased intrathoracic pressure can impede coronary blood flow, leading to myocardial ischemia and subsequent ST-segment elevation[21]. Conversely, in some cases, the decreased intrathoracic pressure associated with lung collapse may result in relative hyperoxygenation of the myocardium, leading to ST segment depression. These ST segment changes in pneumothorax may mimic those seen in acute coronary syndromes, highlighting the importance of considering the clinical context when interpreting ECG findings in these patients[17].

T-wave abnormalities

T-wave abnormalities, such as inverted T-waves or nonspecific T-wave changes, were also commonly observed in pneumothorax patients[22]. These changes may result from the altered myocardial repolarization caused by the mechanical effects of increased intrathoracic pressure on the heart. Furthermore, hypoxemia secondary to ventilation-perfusion mismatch or decreased oxygen diffusion capacity in the collapsed lung regions may contribute to T-wave abnormalities[23]. Hypoxia resulting from impaired lung function due to the pneumothorax can affect the heart's oxygen supply. As a response to reduced oxygen levels, the heart may become ischemic, meaning that it is not receiving enough oxygen. This can lead to changes in the ST-segment of the ECG. Specifically, you may observe ST-segment depression, which is a common ECG finding associated with myocardial ischemia. In addition to ST-segment depression, T-wave changes can also occur on the ECG due to hypoxia. T-wave inversion or flattening may be seen, and this can be indicative of myocardial ischemia or impaired cardiac repolarization, which can occur when the heart is not receiving sufficient oxygen[23]. Severe hypoxia resulting from a large or tension pneumothorax can lead to arrhythmias, which are abnormal heart rhythms. Hypoxia can disrupt the normal electrical signaling within the heart, leading to the development of arrhythmias such as atrial fibrillation, ventricular tachycardia, or bradycardia[1]. These arrhythmias may manifest as irregularities on the ECG. The T-wave changes observed in pneumothorax patients may be transient and resolve upon successful treatment of the underlying condition.

Arrhythmias

A study documented a wide spectrum of arrhythmias associated with pneumothorax, including ventricular arrhythmias, atrial

fibrillation, and conduction disturbances[24]. However, the reported incidence and specific types of arrhythmias varied among studies, and no consistent pattern emerged[25]. The mechanisms underlying arrhythmias in pneumothorax are likely multifactorial. Increased sympathetic activity due to pain, anxiety, or stress associated with the condition may contribute to the development of arrhythmias[26]. Furthermore, alterations in intrathoracic pressure and the resultant effects on cardiac structure and function may predispose patients to arrhythmias. The presence of arrhythmias in pneumothorax patients warrants close monitoring and may require specific management strategies, such as antiarrhythmic medications or electrical interventions, depending on the clinical context and severity of the arrhythmia[1]. Figure 2 shows the specificity and sensitivity of certain ECG features in pneumothorax[26].

Clinical implications

Diagnostic aid

ECG changes can serve as an additional diagnostic tool for pneumothorax. In cases where clinical and radiological findings are inconclusive or unavailable, ECG abnormalities such as a rightward shift in the electrical axis, ST segment deviations, and T-wave abnormalities can provide valuable clues to support the diagnosis of pneumothorax[27]. Integrating ECG findings into the diagnostic algorithm can help expedite diagnosis and guide appropriate management.

Differential diagnosis

ECG changes in pneumothorax may mimic those seen in other cardiac conditions, such as acute coronary syndromes. Therefore, awareness of the specific ECG findings associated with pneumothorax is crucial to avoid misdiagnosis and unnecessary cardiac interventions. Clinicians should consider the clinical context, including the presence of respiratory symptoms, signs of lung collapse, and relevant risk factors when interpreting ECG findings in patients presenting with suspected cardiac abnormalities.

Prompt treatment and monitoring

The recognition of ECG changes in pneumothorax can prompt timely intervention and monitoring. Early detection and treatment of pneumothorax are vital to prevent further respiratory compromise and potential cardiac complications. Monitoring ECG parameters, including changes in the electrical axis, ST segment, and T-wave abnormalities, can help assess the response to treatment and guide the management of pneumothorax.

Risk stratification

The presence of certain ECG abnormalities, such as arrhythmias, may indicate a higher risk of cardiac complications in pneumothorax patients. Close monitoring and risk stratification based on ECG findings can help identify individuals who may require more intensive cardiac evaluation, specialized care, or consideration for early intervention. This approach can improve patient outcomes by enabling timely interventions and appropriate management of cardiac complications associated with pneumothorax.

Prognostic value

Certain ECG changes in pneumothorax may have prognostic implications. For example, significant arrhythmias or persistent ST-segment deviations may indicate a higher risk of adverse cardiac events or respiratory decompensation. Incorporating ECG findings into the prognostic assessment can assist in identifying patients who may benefit from more aggressive monitoring, advanced interventions, or close follow-up care.

Treatment optimization

ECG changes in pneumothorax can guide treatment optimization. By recognizing the impact of pneumothorax on cardiac function, clinicians can implement strategies to mitigate the adverse effects on the heart. This may include optimizing respiratory support, such as adequate lung re-expansion through chest tube placement or noninvasive positive pressure ventilation, to relieve the increased intrathoracic pressure and reduce cardiac strain. Additionally, close monitoring of ECG parameters can help tailor medication regimens and titrate therapy to maintain optimal cardiac function during the management of pneumothorax.

ECG sign	Prevalence in cases / sensitivity (%, n = 82)	Prevalence in controls (%, n = 82)	Specificity (%, n = 82)	p-value for difference in proportions	Point biserial correlation on PT size (Rpb)	Interobserver agreement (Cohen's kappa)
Phasic QRS voltage	25.6	1.2	98.8	<0.001	+0.3, p = 0.01	1.0
Right axis deviation	14.6	3.6	96.3	0.039	0, p = 0.57	1.0
Left axis deviation	7.3	4.9	95.1	0.683	−0.1, p = 0.24	1.0
Incomplete RBBB	13.4	11.0	89.0	0.803	−0.1, p = 0.43	0.8
RBBB	4.9	0	98.8	0.371	0, p = 0.80	1.0
P pulmonale	14.6	0	100	0.001	+0.3, p <0.01	0.9
P-wave inversion in lead I	15.8	0	100	<0.001	+0.5, p <0.01	1.0
Baseline shift with P pulmonale	17.1	0	100	<0.001	+0.4, p <0.01	0.9
T-wave inversion	31.7	2.4	97.6	<0.001	+0.4, p <0.01	0.9
Low QRS voltage	8.5	4.9	95.1	0.547	0, p = 0.97	0.8
QRS voltage ratio aVF/I >2	41.5	22.0	79.3	0.015	+0.2, p = 0.03	1.0
ST segment elevation	18.3	14.6	85.4	0.628	+0.2, p = 0.16	0.9
ST segment depression	1.2	0	100	1.000	−0.1, p = 0.25	1.0
S <1.2 mV in V2	57.3	62.2	37.8	0.596	−0.1, p = 0.54	1.0
S <0.9 mV in V3	46.3	53.7	46.3	0.511	0, p = 0.74	1.0
Prolonged QTc	11.0	2.4	97.6	0.046	−0.1, p = 0.28	1.0
Baseline shift with ST elevation ("spiked helmet sign")	0	0	100	Not available	Not available	1.0

Figure 2. Sensitivity and specificity of ECG features in pneumothorax[26].

Limitations

While ECG is a valuable diagnostic tool in assessing cardiac function, its utility in diagnosing pneumothorax is limited. ECG findings associated with pneumothorax lack sensitivity and specificity, often overlapping with those of other cardiac and pulmonary conditions. Moreover, the manifestations of ECG abnormalities in pneumothorax can be variable and may not correlate with the extent or clinical significance of the condition. Delayed presentation of ECG changes further complicates its diagnostic role, as abnormalities may develop over time or in response to complications such as tension pneumothorax. Interpreting ECG findings in the context of pneumothorax requires careful consideration of clinical factors, including respiratory symptoms, physical examination findings, and radiological imaging results. Without comprehensive clinical assessment, ECG alone may not reliably confirm the diagnosis of pneumothorax.

Future directions

While the existing literature provides valuable insights into ECG changes in pneumothorax, there are several avenues for future research that can further enhance our understanding of this topic. These potential areas of investigation include:

Prospective studies

Conducting well-designed prospective studies with larger patient populations and standardized ECG protocols can provide more robust and reliable data on the prevalence, specific types, and clinical significance of ECG changes in pneumothorax. Long-term follow-up in these studies can also shed light on the prognosis and outcomes associated with different ECG abnormalities.

Mechanistic studies

Further exploration of the underlying mechanisms behind the observed ECG changes in pneumothorax is warranted. Mechanistic studies using animal models or in vitro experiments can help elucidate the effects of altered intrathoracic pressure, cardiac displacement, and hypoxemia on cardiac electrophysiology. Understanding these mechanisms at the cellular and molecular levels can contribute to the development of targeted interventions and therapeutic strategies.

Risk monitoring

Investigating the association between specific ECG changes and the risk of adverse cardiac events or respiratory decompensation can aid in risk stratification of pneumothorax patients. Identifying ECG markers that predict poor outcomes can guide clinicians in determining the optimal level of monitoring, intensity of care, and need for early intervention.

Treatment

Future research should focus on optimizing treatment strategies based on ECG findings in pneumothorax. This can involve evaluating the impact of interventions, such as lung re-expansion techniques or respiratory support modalities, on ECG parameters and cardiac function. Additionally, investigating the role of antiarrhythmic medications or other targeted therapies in mitigating the adverse effects of pneumothorax on cardiac electrophysiology may improve patient outcomes.

Prognosis

Exploring the prognostic value of specific ECG changes in pneumothorax is crucial for risk assessment and patient management. Longitudinal studies examining the association between ECG abnormalities and long-term outcomes, including mortality, recurrence rates, and development of chronic cardiac conditions, can help refine prognostic models and guide clinical decision-making.

Multimodal assessment

Integrating ECG findings with other diagnostic modalities, such as echocardiography or cardiac biomarkers, may provide a more comprehensive assessment of cardiac function in pneumothorax. Combining multiple parameters can enhance diagnostic accuracy, risk stratification, and prognostication, leading to more personalized and targeted patient care.

Artificial intelligence and machine learning

The application of artificial intelligence and machine learning algorithms in analyzing ECG data can potentially improve the detection and interpretation of ECG changes in pneumothorax[27]. Developing predictive models or decision support systems based on these technologies may aid clinicians in the early recognition, diagnosis, and management of pneumothorax-related ECG abnormalities.

Clinical guidelines

The accumulation of further evidence through ongoing research efforts can inform the development of clinical guidelines and recommendations for the evaluation and management of ECG changes in pneumothorax. Consensus statements and expert consensus meetings involving multidisciplinary teams can help standardize approaches to ECG assessment and facilitate evidence-based care delivery.

Conclusion

ECG changes in pneumothorax have emerged as a significant aspect of cardiopulmonary interactions. The findings from this narrative review demonstrate the presence of various ECG abnormalities, including alterations in the electrical axis, ST segment deviations, T-wave abnormalities, and arrhythmias, in patients with pneumothorax. These changes are likely a consequence of the mechanical effects of altered intrathoracic pressure on the heart and the resulting impact on cardiac electrophysiology.

Ethical approval

Ethics approval was not required for this review article.

Consent

Informed consent was not required for this review article.

Sources of funding

The authors received no specific funding for this manuscript.

Author contribution

J.M., H.A., N.I., V.K., and U.N.K.: concept; C.P.K., F.P., and H.A.: data collection; S.K., M.T.H., D.K., D.R., and F.P.: design; S.K. and A.M.: data analysis; C.P.K., F.P., H.A., S.K., M.T.H., D.K., D.R., F.P., S.K., and J.M.: writing; A.M. and J.M.: supervision.

Conflicts of interest disclosure

The authors declare no competing interests.

Research registration unique identifying number (UIN)

1. Name of the registry: not applicable.
2. Unique identifying number or registration ID: not applicable.
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): not applicable.

Guarantor

Amin Mehmoodi.

Data availability statement

Not applicable.

Provenance and peer review

Not applicable.

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