Chest Radiography in the Intensive Care Unit - Need to Know Emergency Findings

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Abstract

Conventional chest radiography, also known as a chest X-ray, is a fundamental imaging tool for diagnosing cardiopulmonary disorders in critically ill patients within the intensive care unit (ICU). The interpretation of these radiographs is complicated by intricate radiological features and the frequent presence of lines, tubes, and other monitoring devices, which can obscure critical findings. Many cardiopulmonary conditions exhibit similar radiographic signs, such as airspace opacification, which complicates diagnosis. Typically, emergency findings on ICU chest X-rays include misplaced lines and tubes, iatrogenic pneumothorax and pneumomediastinum, congestive heart failure, pleural and pericardial effusions, foreign bodies, atelectasis, and various forms of pneumonia. Recognizing these conditions promptly is essential for effective patient management. This review article aims to explore the common emergency findings observed in ICU chest radiographs, shedding light on the complexities that healthcare professionals face in diagnosing and treating cardiopulmonary disorders in critically ill patients.

Keywords: Radiographic interpretation, Intensive Care Unit (ICU), Chest radiography (X-ray), Cardiopulmonary disorders, Emergency findings

Sažetak:

Radiogrami torakalnih organa u jedinicama intenzivnog liječenja – hitni nalazi koje je važno prepoznati

Konvencionalni radiogrami torakalnih organa, poznati i kao RTG toraksa, temeljni su dijagnostički alat za dijagnosticiranje kardiopulmonalnih poremećaja u kritično bolesnih pacijenata u jedinicama intenzivnog liječenja. Interpretacija snimki otežana je kompleksnim radiološkim značajkama te čestim prisustvom brojnih katetera, drenova te naprava za monitoriranje pacijenta koji mogu prikriti važne nalaze. Mnoga kardiopulmonalna stanja pokazuju slične radiološke znakova poput opacifikacije plućnog parenhima, što otežava postavljanje dijagnoze. Tipični hitni nalazi na radiogramima torakalnih organa iz jedinica intenzivnog liječenje uključuju pogrešno postavljenje katetere i tubuse, jatrogeni pneumotoraks i pneumomedijastinum, kongestivno srčano zatajenje, pleuralni i perikardni izljev, strana tijela, atelektazu, i razne vrste pneumonije. Promptno prepoznavanje ovih entiteta od iznimne je važnosti za učinkovito liječenje pacijenata. Ovaj pregledni članak donosi neke od najčešćih hitnih nalaza na radiogramima torakalnih organa iz jedinica intenzivnog liječenja te pruža uvid u izazove s kojima se radiolozi i drugi liječnici susreću pri dijagnosticiranju i liječenju kardiopulmonalnih poremećaja u kritično bolesnih pacijenata.

Ključne riječi: radiološka interpretacija, jedinice intenzivnog liječenja, radiogrami torakalnih organa, kardiopulmonalni poremećaji, hitni nalazi

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Introduction

Chest radiography (X-ray) is a key tool for diagnosing cardiopulmonary disorders in ICU patients, but interpreting these X-rays presents several challenges. High imaging volume, variable image quality from portable X-rays, and the complexity of overlapping radiological features of different pathologies make diagnosis difficult. Using supine anteroposterior (AP) views instead of the ideal posteroanterior (PA) views, along with superimposed medical devices like catheters, tubes, and monitors, further complicates interpretation. Misplaced devices can also obscure critical findings or even cause complications. To improve diagnosis, optimal radiographic techniques, timely image access, and advanced technologies, such as deep learning algorithms employed by atrificial intelligence (AI), can support accurate and rapid interpretation, leading to better patient outcomes [1-4].

Review article

This review article will address several of the most prevalent emergency pathological conditions observed in ICU chest radiographs. These include cardiogenic and noncardiogenic pulmonary edema, pulmonary aspiration disease, atelectasis, pleural effusion, pneumothorax, pericardial effusion, pneumopericardium, misplaced lines, tubes, and other medical devices, as well as diaphragmatic hernia.

Cardiogenic and noncardiogenic pulmonary edema

Cardiogenic pulmonary edema, a frequently observed entity in ICU chest radiographs, exhibits a spectrum of imaging characteristics facilitating its prompt identification and accurate diagnosis. It originates from the gradual extravascular movement of fluid into the pulmonary interstitium and alveoli. Distinct imaging features mark its progression. Early manifestations include pulmonary venous hypertension, which is evident through the enlargement of the vascular pedicle width and redistribution of blood into upper lobe vessels. With hydrostatic pressure elevation to 20-25 mmHg, fluid translocates from intravascular spaces to the surrounding interstitium, leading to thickening of the interlobular fissures, peribronchovascular cuffing, and blurring of the pulmonary vessel walls (Figure 1). Subsequently, alveolar flooding occurs, manifesting as perihilar opacities (''batwing sing", Figure 2). Furthermore, less commonly seen noncardiogenic pulmonary edema shares similar imaging characteristics. This condition can arise from direct lung damage, such as pneumonia or inhalational injury, resulting in acute respiratory distress syndrome (ARDS) (Figure 3). Also, indirect causes may include conditions like acute pancreatitis, sepsis, severe trauma with shock, lung injury caused by mechanical ventilation, and transfusion-related acute lung injury (TRALI) [5].

Figure 1: Heart failure - cardiogenic interstitial pulmonary edema. In the context of heart failure-induced cardiogenic interstitial pulmonary edema, Figure 1 displays bilaterally prominent interstitial lung markings and peribronchovascular cuffing. Additionally, minimal pleural effusion was observed. Cardiomegaly is evident, along with an increased width of the vascular pedicle.

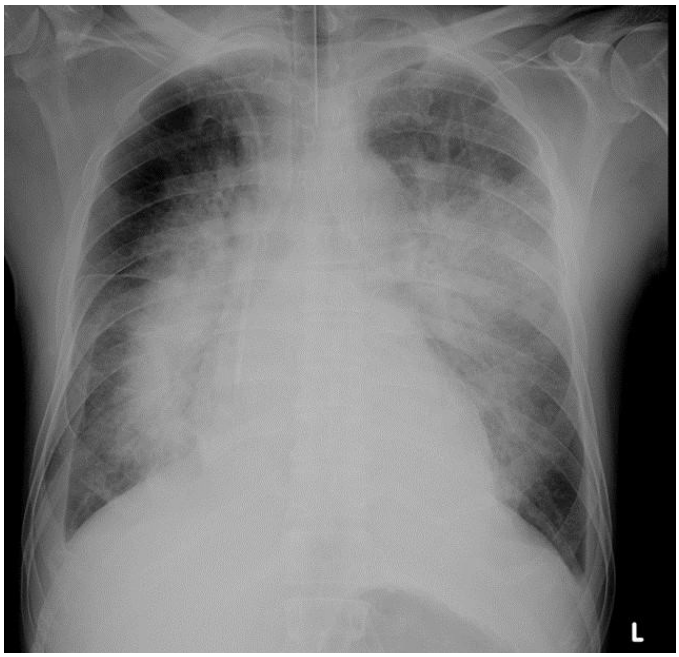

Figure 2: Heart failure - cardiogenic alveolar pulmonary edema. In the context of heart failure-induced cardiogenic alveolar pulmonary edema, Figure 2 displays bilateral symmetrical perihilar patchy lung shadowing, commonly referred to as the "batwing sign." The presence of cardiomegaly and bilateral pleural effusions is notable. Moreover, both the endotracheal tube and central venous line are appropriately positioned.

Figure 3: Acute Respiratory Distress Syndrome (ARDS) – Noncardiogenic Alveolar Pulmonary Edema. The babygram of a newborn reveals bilateral diffuse lung opacities with visible air bronchograms, indicative of acute respiratory distress syndrome (ARDS). No pleural effusion or heart enlargement is observed. The positioning of the endotracheal tube, peripherally inserted central catheter (PICC), and nasogastric tube is correct.

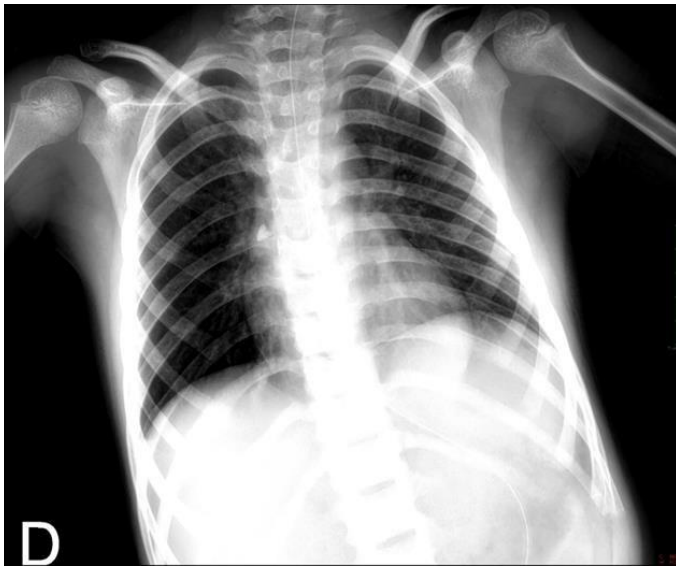

Figure 4: Inhaled foreign body. A triangular-shaped, mineral-density foreign body resembling a "tooth" is observed in the projection of the right main bronchus. No signs of overinflation or atelectasis were noted. Additionally, the nasogastric tube appears to be correctly inserted.

Pulmonary aspiration disease

Aspiring solid or liquid substances into the lower airways can lead to various pulmonary complications, including lobar or segmental pneumonia, bronchopneumonia, lung abscess, and empyema. These conditions typically affect the posterior segment of the upper lobes and the superior segment of the lower lobes. Among adults, alcoholism stands out as a significant predisposing factor, along with general anesthesia, loss of consciousness, and structural abnormalities of the pharynx and esophagus. The clinical and radiologic presentations of these pulmonary complications vary widely, ranging from asymptomatic focal inflammatory reactions with minimal radiologic abnormalities to severe, life-threatening diseases. In children, foreign body aspiration is a common occurrence, often resulting in obstructive lobar or segmental overinflation or atelectasis. Notably, the foreign body may not be visible on chest radiographs due to a lack of radiopacity (Figure 4).

In cases of massive gastric content aspiration, patients may exhibit an extensive, patchy broncho-pneumonic pattern on radiographs (Figure 5). Aspiration of infectious material can result in necrotizing consolidation and abscess formation within the lungs (Figure 6) [6].

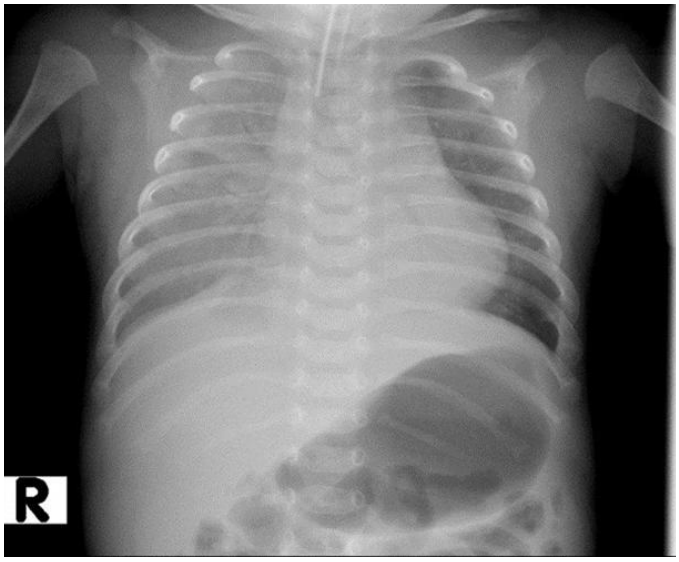

Figure 5: Aspiration pneumonia. The right lung parenchyma exhibits complete homogeneous shading, indicative of right-sided aspiration pneumonia, with visible air-bronchograms. The endotracheal tube is appropriately positioned. No evidence of pleural effusion or cardiomegaly was observed.

Figure 6: Pulmonary abscess. A cavitary lesion is identified in the right lung, characterized by a thick wall and an air-fluid level, surrounded by irregular parenchymal opacities. No indications of pleural effusion or cardiomegaly were observed.

Atelectasis

Lung collapse, also known as atelectasis, refers to the diminished inflation of all or part of the lung. It occurs due to various mechanisms. One of the most common is the loss of aeration and subsequent resorption of air distal to an obstructed airway, leading to decreased lung volume. When atelectasis affects only part of a lung lobe, it is termed partial or linear atelectasis, while the involvement of an entire lobe is referred to as lobar atelectasis [7]. Several factors can contribute to atelectasis, including endoluminal masses such as bronchogenic carcinoma, external compression from enlarged lymph nodes, mucus impaction seen in conditions like asthma or cystic fibrosis, foreign body inhalation (especially in young children, Figure 4), and inadequate ventilation, often due to a misplaced endotracheal tube (Figure 7).

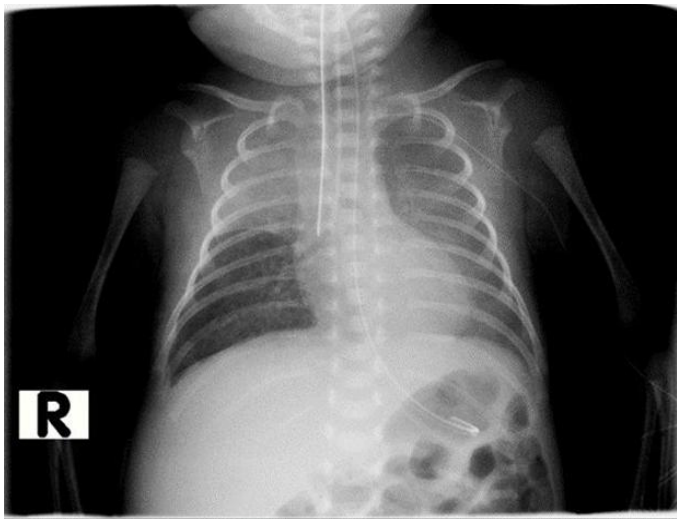

Figure 7: Atelectasis. A misplaced endotracheal tube, with its tip erroneously positioned in the main right bronchus, leads to atelectasis of the upper right lung lobe. Concurrently, left perihilar incipient homogeneous opacities with air bronchograms indicate the onset of left lung atelectasis formation. The peripherally inserted central catheter (PICC) and nasogastric tube are positioned correctly.

A collapsed lung appears denser than normally inflated lung tissue, and the so-called "silhouette sign" (loss of the structure's outline) is a crucial imaging finding that suggests atelectasis, necessitating further evaluation [8].

Pleural effusion

Pleural effusion, a common occurrence among ICU patients, arises from disrupted fluid dynamics in the pleural space and often complicates various life-threatening conditions such as heart failure, fluid overload, hypoproteinemia, infection, pulmonary embolism, surgery, neoplastic disease, subphrenic inflammatory processes, trauma, and ascites. These effusions can vary in chemical composition, ranging from transudates to exudates, blood, chyme, and pus. However, discerning between these compositions is impossible on a supine chest radiograph, the primary imaging modality for ICU patients. Radiographic features of pleural effusion on a supine chest X-ray are nonspecific and pose challenges in analysis. Gravitational-conducted accumulation of pleural fluid, particularly in volumes exceeding 300 ml, typically manifests as posterobasal opacities.

Typical radiographic findings include loss of diaphragm contour with homogenous opacification towards the lung base, blunting of costophrenic angles, elevated hemidiaphragm with lateral dome displacement, homogenous density increase at the lung apex (known as "pleural cap") and along interlobar fissures with a characteristic biconvex shape, and widened mediastinum (Figure 8).

Figure 8: Pleural effusion. Bilaterally homogeneous opacification extending towards the lung base is observed, accompanied by effacement of the costophrenic angles. Additionally, prominent interstitial lung markings and peribronchovascular cuffing are noted. Furthermore, cardiomegaly is evident with an increased vascular pedicle width.

In cases of inconclusive findings, additional imaging, such as lateral decubitus films, may be performed to differentiate between loculated and free effusions. Lateral decubitus films are acquired when the patient is positioned on the side suspected of having an effusion, facilitating visualization of position-dependent fluid accumulation [9].

Iatrogenic pneumothorax

Pneumothorax is characterized by the presence of free gas in the pleural space. It can manifest in several forms: primary spontaneous, secondary spontaneous (occurring in the presence of underlying lung disease), and iatrogenic (resulting from invasive procedures such as pulmonary needle biopsy, central venous line placement, positive pressure ventilation, and other thoracic and abdominal procedures). Among these, iatrogenic pneumothorax is a potential consideration in ICU patients experiencing sudden pleuritic pain, dyspnea, tachypnea, and tachycardia. As a complication, tension pneumothorax may arise when pleural space pressure remains positive throughout the respiratory cycle [10]. In supine ICU patients, a typical radiological feature of pneumothorax is the visualization of a visceral pleural line devoid of distal lung markings, particularly prominent at the lung bases, leading to enlargement of the costophrenic angle, known as the "deep sulcus sign" (Figure 9).

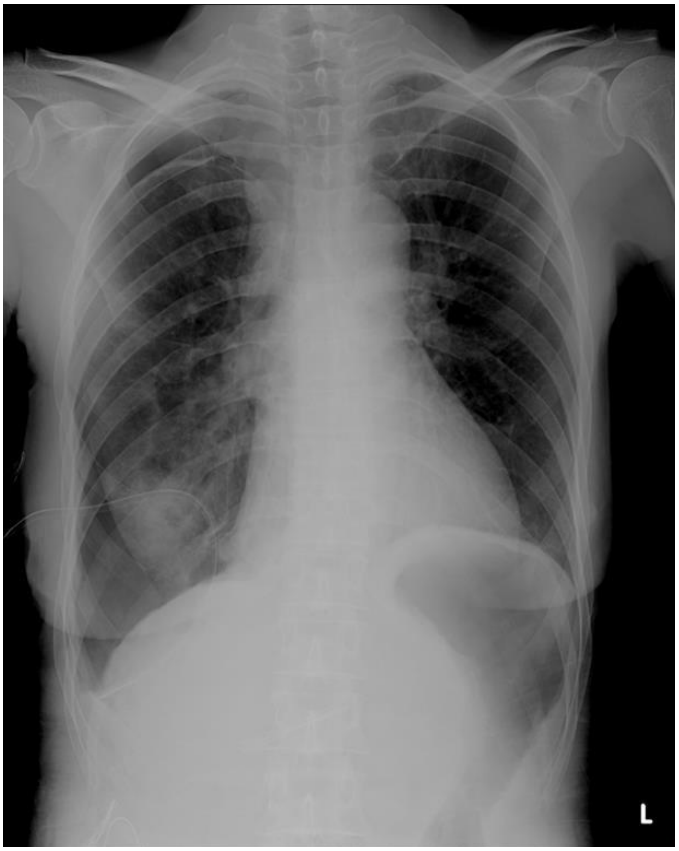

Figure 9: Pneumothorax. The radiograph reveals increased transparency of the enlarged right costophrenic angle, known as the "deep sulcus sign", which is indicative of a pneumothorax. It is accompanied by visualizing a visceral pleural line without distal lung markings. Additionally, there is a blunted appearance at the tip of the right costophrenic angle, suggesting the presence of minimal ipsilateral pleural effusion or hydropneumothorax. Notably, a chest tube is correctly positioned at the right costophrenic angle.

A pneumothorax is deemed significant when the distance from the parietal pleural surface to the lung edge exceeds 2 cm, warranting drainage intervention. However, it is crucial to differentiate genuine pneumothorax from artifacts such as skin folds, companion shadows, scapulae, or previous lung surgery, which may mimic its appearance on radiographs. Immediate post-treatment radiographs are vital for detecting complications and ensuring satisfactory positioning of tubes or lines [11, 12].

Pericardial effusion and pneumopericardium

The average volume of physiological pericardial fluid is typically less than
50 ml. Effusions smaller than 200 ml are often not visible on chest radiographs. The most sensitive indicator of pericardial effusion on a chest radiograph is an enlargement of the cardiac silhouette, characterized by a cardiothoracic ratio exceeding 50%. While this criterion demonstrates reasonable sensitivity (71%), its specificity is relatively low (41%). Pericardial effusion typically symmetrically expands the pericardial contour, resulting in a "globular" configuration, commonly referred to as the "water bottle sign" (Figure 10) [13].

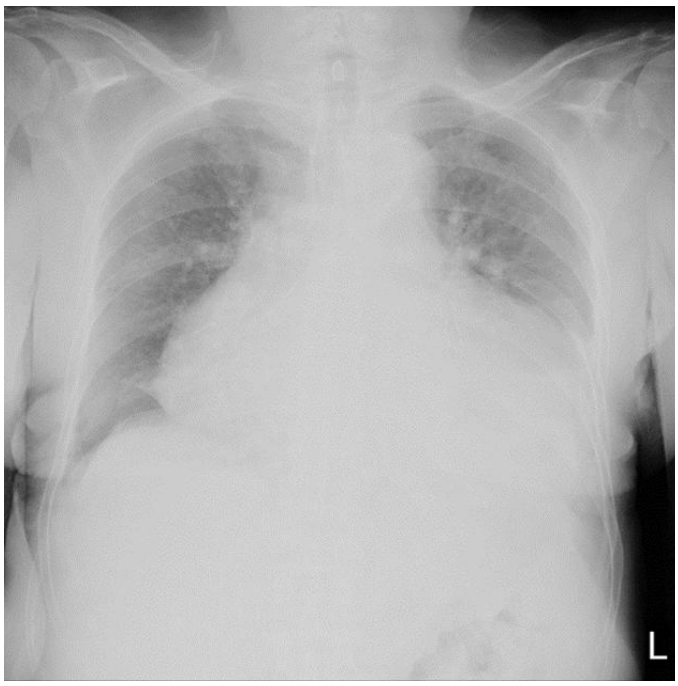

Figure 10: Pericardial effusion. A markedly enlarged heart with a globular contour typically indicates pericardial effusion, often referred to as the "water bottle sign." Concurrently, bilateral peribronchovascular cuffing accompanied by prominent interstitial lung markings suggests the presence of heart failure.

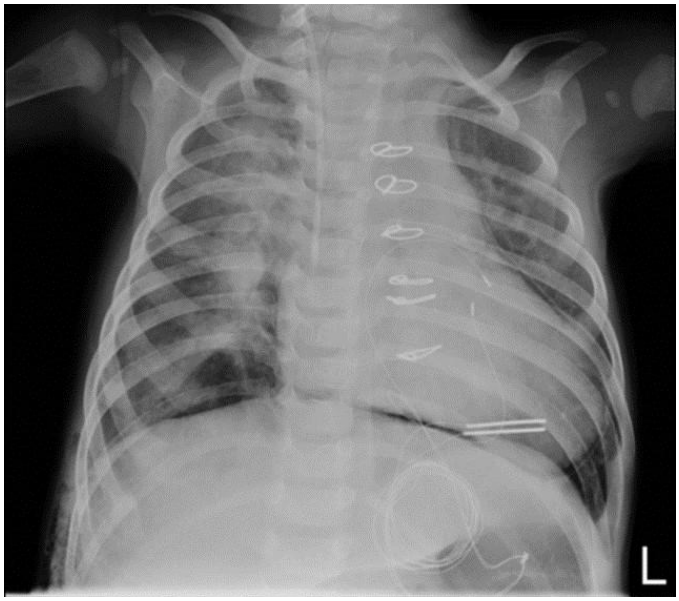

Figure 11: Pneumopericardium. The presence of a radiolucent zone surrounding the heart, commonly known as the "halo sign," along with a continuously delineated left diaphragm, indicates pneumopericardium. Additionally, inhomogeneous perihilar opacities are noted in the right lung. The central venous line is appropriately positioned. Sternotomy wires and epicardial electrodes are also visible.

Pneumopericardium signifies the loss of pericardial integrity, resulting in the presence of free air within the pericardial sac. In ICU patients, typical causes of pneumopericardium include invasive procedures, such as thoracic surgery and positive pressure ventilation. Small amounts of free air in the pericardium may not be visualized on chest radiographs. However, when present in sufficient volume, the distinct radiolucent zone surrounding the heart becomes evident, known as the "halo sign." Radiographically, the primary challenge is distinguishing pneumopericardium from the more prevalent pneumomediastinum. One useful differentiating feature is the so-called "continuous left diaphragm sign" (Figure 11). Additionally, similar to pericardial effusions, a large pneumopericardium has the potential to cause tamponade, resulting in the "small heart sign," characterized by a sudden reduction in cardiac diameter exceeding 2 cm [14].

Misplaced lines, tubes, and other devices

ICU patients require continuous monitoring of vital functions and mechanical and pharmacological support provided through various devices, including central venous lines, Swan-Ganz lines, pacemaker electrical leads, left ventricular assistance devices, endotracheal tubes, chest tubes, and nasogastric tubes. Chest radiographs play a central role in ensuring the correct positioning of these devices and monitoring for common post-placement complications. The ideal positioning of correctly implemented lines, catheters, devices, and tubes on chest radiographs is as follows:

- Central venous line: The tip should be positioned in the superior vena cava, slightly above the right atrium (Figure 12).
- Swan-Ganz catheter: The tip should be positioned in the right or left main pulmonary artery.
- Pacemaker electrical leads: The tips of the leads should project against the right atrium and ventricle. In the case of implantable cardioverter-defibrillators (ICDs) or biventricular pacemakers, the tips of the leads should project against the right atrium and both ventricles (Figure 13).
- Left ventricular assistance device: Inserted into the ascending aorta, passing through the aortic valve, with the tip positioned in the left ventricle.
- Endotracheal tube: The tip should be positioned approximately 5 cm ± 2 cm from the carina at the T3 or T4 vertebral body level.
- Chest tube: In cases of pneumothorax, the tip should be positioned apically to facilitate the evacuation of gas. For pleural effusion, the tip should be placed basally for fluid drainage. In instances of loculated pleural fluid, the tip should be positioned in the specific location of the loculation.
- Nasogastric tube: The tip should be positioned within the stomach, extending beyond the cardia.

These guidelines help ensure proper device function and reduce the risk of complications in ICU patients, facilitating effective management and care [15-18].

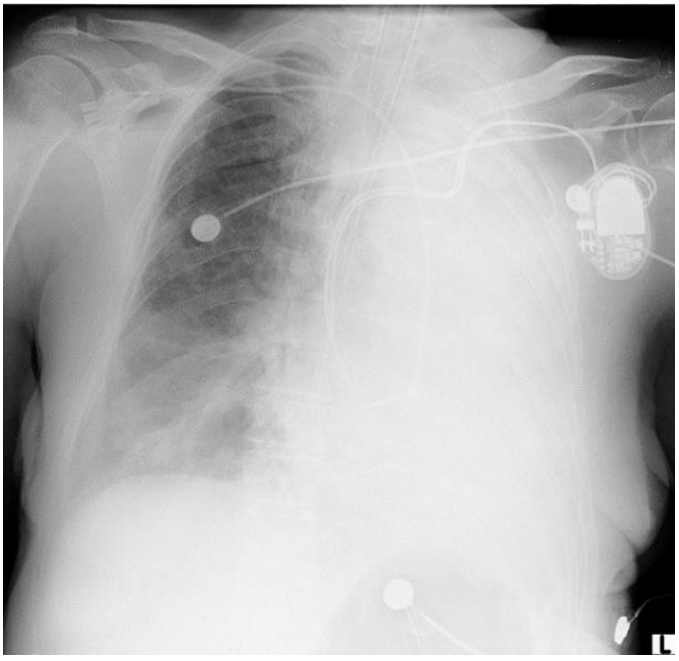

Figure 12: Misplaced central venous line. A central venous line was mistakenly installed into the right subclavian artery instead of the intended right subclavian vein, resulting in its projection into the ascending aorta. An endotracheal tube was also misplaced, with its tip positioned in the right main bronchus, resulting in atelectasis of the left lung. However, a nasogastric tube is correctly positioned. Furthermore, a dual-chamber cardiac pacemaker is in situ, with the appropriate positioning of both atrial and ventricular lead tips.

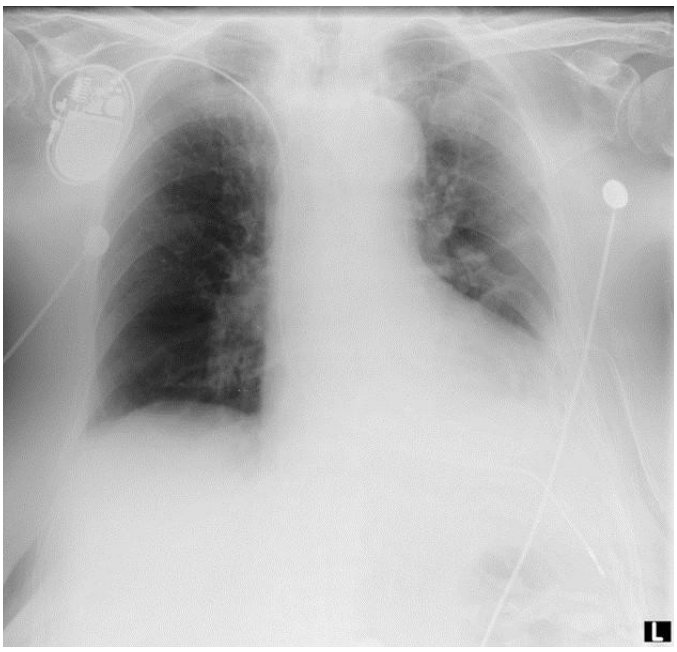

Figure 13: Misplaced pacemaker electrical lead. A single-chamber cardiac pacemaker is present, with the ventricular lead tip improperly positioned outside the cardiac silhouette, notably displaced into the left costophrenic angle. Cardiomegaly is evident, indicative of heart failure. Additionally, there is a left pleural effusion, for which a chest tube has been correctly inserted.

Diaphragmatic hernia

A diaphragmatic hernia is a defect in the diaphragm that causes abdominal organs to be displaced into the thoracic cavity. These hernias can occur as either congenital anomalies or acquired defects in the diaphragm. In the context of ICU chest radiographs, undetected diaphragmatic hernias may present as an unexpected finding in trauma patients, typically indicating an acquired type of hernia. Conversely, they can also be identified postnatally in newborns experiencing respiratory distress, often indicating an undiagnosed congenital diaphragmatic hernia (Figure 14). Regardless of its origin, a diaphragmatic hernia represents a life-threatening anomaly that should not be overlooked or misdiagnosed. Prompt identification and appropriate management are crucial for reducing associated risks and ensuring optimal patient outcomes [19].

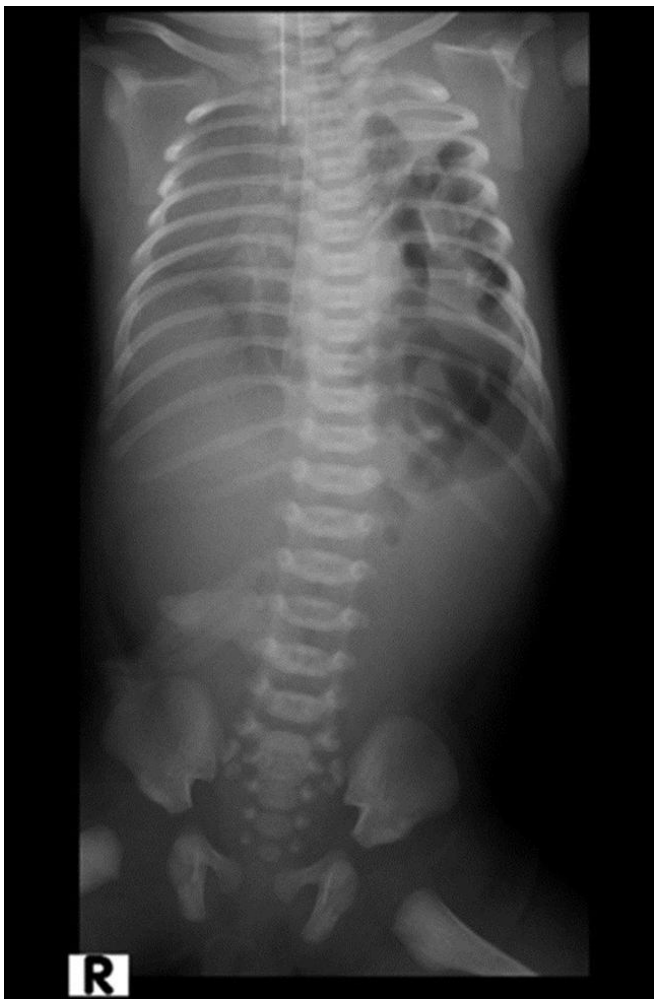

Figure 14: Congenital left-sided diaphragmatic hernia. In a babygram, gas-filled bowel loops are observed projecting into the left thorax, accompanied by contralateral displacement of the heart and decreased lung ventilation. Additionally, a nasogastric tube is present, but its tip is positioned above the anatomically expected esophagogastric junction, raising suspicion of intrathoracic displacement of the stomach. The endotracheal tube is correctly positioned.

Conclusion

Chest radiography remains the preferred imaging modality for diagnosing cardiopulmonary disorders in ICU patients due to its accessibility, rapidity, and cost-effectiveness compared to other imaging techniques. Swiftly identifying emergency findings is a significant challenge that necessitates thorough training. Ultimately, the paramount objective is to save patients' lives, a task achievable through extensive knowledge and rigorous practice.

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Conflict of Interest: Each author declares that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangement, etc.) that might pose a conflict of interest in connection with the submitted article.

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