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ABNORMAL FREE GAS COLLECTION IN RADIOGRAPHY: A PICTORIAL REVIEW

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Abstract

An abnormal free gas collection in the thorax and abdomen is a condition in which air or gas is trapped in the thorax and abdominal cavity thatis normally not present.Radiological examination plays a very important role in detecting the presence, volume, location, and complicationof abnormal gas. Some of these conditions can represent classic radiological appearances that we can find in everyday practice.

Keywords: *abnormal gas collection, pneumoperitoneum, pneumothorax, radiology*

INTRODUCTION

An abnormal free gas collection is divided into free gas that is located in the thorax cavity (pneumothorax, pneumomediastinum, pneumopericardium, subcutaneous emphysema) and free gas that is located in the abdominal cavity (pneumo peritoneum, pneumo retro peritoneum, pneumatosis intestinalis, pneumobilia, portal venous gas).

This situation can be the result of interstitial or cystic lung disease, trauma, infection, positive pressure ventilation, bowel perforation, and other complications associated with medical interventions. The severity of which varies, from harmless to life-threatening condition. Sometimes, clinicians find difficulty in detecting this abnormality from history taking and physical examination alone, especially when the air volume is very small. Thus, radiological examination plays an essential part in the detection of the presence, volume, location, or complication of abnormal gas. This information is considered helpful in providing direction for further management.

PNEUMOTHORAX

Pneumothorax is a collection of air in the pleural space, either from leaking through a hole in the lung or from a penetrating chest injury.(1) The main symptoms of pneumothorax are sudden chest pain, dyspnea, and dry cough. Pneumothorax is caused by the rupture of bullae, trauma, and iatrogenic complication after an intervention, such as thoracentesis and positive pressure ventilation.(2) If it is not caused by trauma, it is referred to as spontaneous; this may be primary (not associated with an underlying cause) or secondary to preexisting significant pulmonary disease.(3)

The sudden entry of air into the pleural space causes the negative pressure to rise higher than the intra-alveolar pressure,collapsing the lung.(1,4) The parietal pleura remains adjacent to the inner surface of the chest wall, but the visceral pleura retracts toward the hilum with the collapsing lung. The visceral pleura becomes visible as a thin white line outlined by air on both sides, marking the outer border of the lung and indicating the presence of the pneumothorax (Figure 1). Even as the lung collapses, it tends to maintain its usual lung-like shape so that the curvature of the visceral pleural line parallels with the curvature of the chest wall.(4)

A tension pneumothorax is a serious type of pneumothorax whereby air enters but cannot leave the pleural space. A one-way-valve mechanism between the involved lung and the pleura leads to continuous leakage of air into the pleural cavity. The accumulation of air within the pleura causes a shift in the

heart and mediastinal structures away from the affected side, the ipsilateral diaphragm to be displaced downwards (especially in positive pressure ventilation), and cardiopulmonary compromise by impairing venous return to the heart. Tension pneumothorax is alife-threatening medical emergency situation.[2,4,5]

Radiographic findings of tension pneumothorax are the same as a simple pneumothorax with the addition of mediastinal displacement, flattening of the heart border, diaphragmatic inversion, increased intercostal space, and total or subcostal lung collapse, reflecting the expansion of the affected hemithorax (Figure 2).[4]

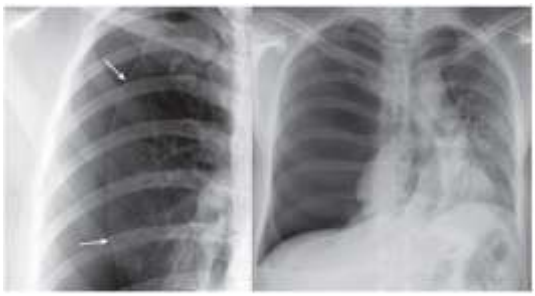

Figure 1 (Left) Visceral pleura (white arrow) retracts toward the hilum along with the collapsing lung with the contour paralleling the curvature of the adjacent chest wall. Figure 2 (Right) Tension pneumothoraxwith mediastinal shift and collapse of the entire rightlung.[4]

PNEUMOMEDIASTINUM

Pneumomediastinum represents the presence of air in the mediastinum except for the lumens of the esophagus and airway. The air can come from the alveoli, tracheobronchial trees, and esophagus, or from the passage of abnormal extraluminal gas into the thorax from the neck, retroperitoneum, or chest wall. The symptoms include chest pain (most common), dyspnea, sore throat, and dysphagia.[6]The radiographic signs of pneumomediastinum appear as radiolucent lines or bubbles outlining the mediastinal structures that are not normally visible or as an outwardly elevated mediastinal pleura (Figure 3). Other signs of pneumomediastinum include the tubular artery sign, rings around the artery sign, double bronchial wall sign, spinnaker sail sign, continuous diaphragm sign, and Naclerio's V sign (Figure 3–8).[2]

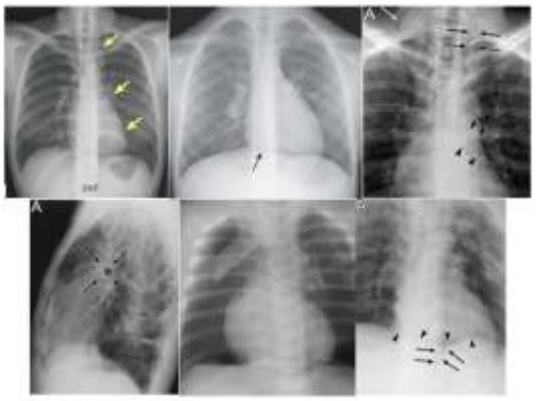

Figure 3 (Top right) Pneumomediastinum appears as radiolucent lines or bubbles outlining the mediastinal structures that are not normally visible or as an outwardly elevated mediastinal pleura.[2] Figure 4 (Top middle) Continuous diaphragm sign:Air is outlining the central portion of the diaphragm beneath the heart, producing an unbroken line in the superior surface of the diaphragm extending from one lateral chest wall to the other.[4] Figure 5 (Top left) Tubular artery sign:A visualization of both sides of a vessel (arrow). Double bronchial sign:A visualization of both sides of the bronchial wall due to the air in the bronchus and the air surrounding the wall (arrowhead).[2] Figure 6 (Bottom right) Ring around the artery sign:It appears as a lucent ring (arrow and asterisk) that surrounds the right pulmonary artery (seen on lateral projection).[2] Figure 7 (Bottom middle) Spinnaker sail (angel wing) sign:A wedge-shaped opacity from the thymic tissue that displaced upward and laterally from its usual location, usually found in children.[7] Figure 8 (Bottom left) Naclerio V sign:A V-shaped air collection that consists of air along the left aortic border and medial left hemidiaphragm (arrow). Continuous diaphragm (arrowhead).[2]

PNEUMOPERICARDIUM

Pneumopericardium is the collection of air in the pericardial sac. It is a rare but potentially life-threatening condition.[2,8] Pneumopericardium is usually caused by direct penetrating injuries to the pericardium, either caused by iatrogenic (positive pressure ventilation, cardiac surgery) or accidents (blunt or penetrating trauma).[4,8] The main clinical symptomsare chest pain, and radiating pain, dyspnea, and palpitations.[2] Pneumopericardium produces a continuous band of lucency that encircles the heart, bound by the parietal pericardial layer, which extends no higher than theroot of the great vessels (corresponding to the level of the main pulmonary artery) (Figure 9).[4,8]

SUBCUTANEOUS EMPHYSEMA

Subcutaneous emphysema occurs when air accumulates at the level of subcutaneous fatty tissue and superficially to the deep fascia that covers the skeletal muscle planes.[2] Air can extend into the soft tissue of the neck, chest, and abdominal walls from the mediastinum, or it can dissect the subcutaneous tissue from a thoracotomy drainage tube or a penetrating injury to the chest wall.[4] The most common causes are trauma and iatrogenic complications (after a surgical procedure or insertion of a chest tube). The clinical symptom of subcutaneous emphysema is swelling around the neck accompanied by pain in the chest.[2] Subcutaneous emphysema appears as multiple lucencies in the subcutaneous tissue on radiographs. When air involves deeper muscle tissues, it can appear as linear lucencies with a linear disposition following the direction of the fascial planes or muscle fibers (Figure 10).[2]Although it seems radiographically dramatic, it usually produces no serious clinical effects by itself.[4]

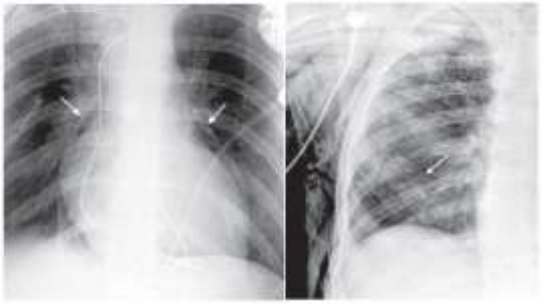

Figure 9 (Left) Pneumopericardium:It is shown by the visible parietal pericardium (white arrow) outlining air around the heart in the pericardial space. The air does not extend above the reflection of the aorta and main pulmonary artery.[4,8] Figure 10 (Right) Subcutaneous Emphysema:Air dissecting along muscle bundles produces a comb-like characteristic / striated appearance (white arrows).[4]

PNEUMOPERITONEUM

Pneumoperitoneum is a free gas in the peritoneal cavity that usually indicates bowel perforation. The main cause of pneumoperitoneum is a perforation/disruption of the wall of a hollow viscus. Hollow-organ perforation is very threatening and one of the most common reasons for surgical emergencies.[9–11]

There are 4 etiologic categories of pneumoperitoneum: iatrogenic(comprising surgery, endoscopy, feeding tube placement, peritoneal dialysis), spontaneous(peptic ulcer, bowel obstruction, intestinal ischemia, toxic megacolon, acute appendicitis, necrotizing enterocolitis, tuberculosis), traumatic, and miscellaneous (drugs, female-genital-related causes).[12]

Common signs and symptoms are abdominal pain, vomiting, abdominal distension, constipation, fever, diarrhea, tachycardia (pulse > 110/min), hypotension (systolic blood pressure < 100 mmHg), urine output (<30 mL/h), and tachypnea (respiratory rate > 20/min). The clinical presentation varies according to the site of perforation.[9]

Plain radiography is the fastest, most efficient, and cheapest imaging examination

for detecting intraperitoneal free air. Very small amounts of extraluminal free air still can be visualized on plain radiographs.[11] An abdominal radiograph and erect chest radiograph are requested together when looking for a pneumoperitoneum because chest radiograph is very sensitive for detecting free abdominal gas since it can detect as little as 2–3 mL; free gas is seen as a rim blackness beneath and very closely opposed to the curve of the diaphragm.[10] Supine radiograph is also used to compare with erect and decubitus abdominal radiographs in detecting pneumoperitoneum.[11]

Air will rise to the highest part of the abdominal cavity opposite to the direction of gravity. In an upright position, free air will usually reveal itself under the diaphragm as a crescentic-lucency shape that parallels with the undersurface of the diaphragm. The size of the crescent will be roughly proportional to the amount of free air. The larger the amount of free air, the larger the crescent. Free air is easier to recognize under the right hemidiaphragm because there is usually only the soft tissue density of the liver in that location. Free air is more difficult to recognize under the left hemidiaphragm because air-containing structures, like the fundus of the stomach and the splenic flexure, already reside in that location and may be mistaken for free air.[4]There are many signs of pneumoperitoneum (Figures 11–22).

Figure 11 (Left) Subphrenic lucency sign: Free air is visible under the bilateral hemidiaphragm. [9] Figure 12 (Top right) Continuous diaphragm sign: Continuous lucency extending beneath diaphragm from the middle to the lateral of both sides. [15] Figure 13 (Bottom Right) Left lateral decubitus view shows a crescent of air between the outer edge of the liver and right abdominal wall. [4]

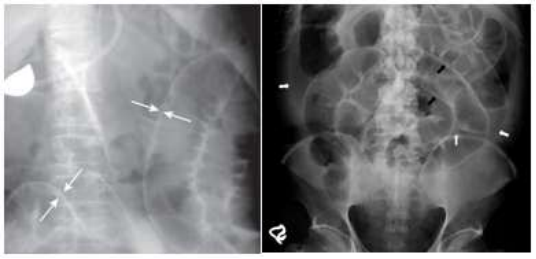

Figure 14 (Left) Rigler's / double wall sign:[4] Bowel wall becomes visible in both sides as it is outlined by gas within and outside of the bowel. Normally, only the gas inside bowel wall is visible.[10] Figure 15 (Right) Telltale triangle sign: Free air is accumulating among three overlapping adjoining bowel loops or two bowel loops, and the parietal peritoneum is forming a triangular shape lucency (white arrow).[12]

Figure 16 (Top left) Doge cap sign / Morison pouch sign:[11]Air accumulated in Morison pouch is forming a triangle-shaped lucency. The location is not higher than the right 11th rib because it is restricted above the bare area of the liver.[9,11,12] Figure 17 (Top right) Ligamentum teres sign: extraluminal air in the fissure of ligamentum teres → vertical linear lucency 2–7 mm wide, 6–20 mm long, in the RUQ (black arrows).[16] Figure 18 (Bottom left) Cupola / saddlebag / mustache sign:[11]An air accumulation underneath the central tendon of the diaphragm in the midline (caudal side from heart), forming a shape like a dome or an inverted cup.[9] Figure 19 (Bottom right)

Leaping dolphin sign (arrow):[11] Air under the long costal muscle slip of the diaphragm indented the adjacent air-filled space in RUQ. Hyperlucent liver sign (dotted arrow): Free gas anterior of the liver surface that is causing a reduction in liver opacity.[9,11,12]

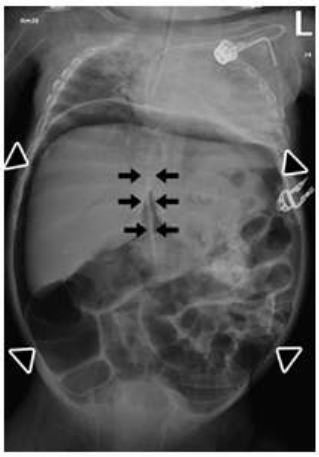

Figure 20 Extensive pneumoperitoneum with multiple signs.[15] Football sign:Large oval lucency extends along the craniocaudal long axis of the abdomen, resembling the shape of an American football.[15] Falciform ligament / silver sign: The falciform ligament, a ligament attaching the liver to the anterior abdominal wall / a remnant of the umbilical vein, becomes visible if outlined by free gas (black arrow).[4,10] Liver edge sign: liver edge may become easily visible due to the surrounding free intraperitoneal gas. Normally the liver is outlined by peritoneal fat.[10]

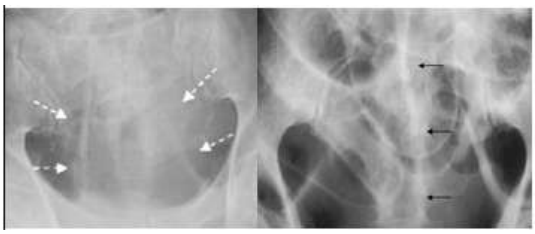

Figure 21 Inverted V sign: [12] Free air outlining the lateral of umbilical ligaments makes "inverted V" shaped structures visible in the lower abdomen as it courses inferiorly and laterally from the umbilicus.[9,11,12]

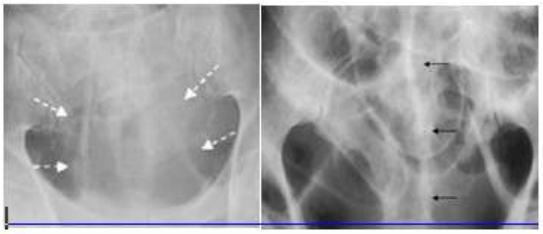

Figure 22 Urachus sign:[12] Free air outlining thin middle of umbilical ligaments forms a linear structure in the lower abdomen from the umbilicus to the dome of the urinary bladder.[9,11,12]

PNEUMORETROPERITONEUM

Pneumoperitoneum is an abnormal gas collection in the retroperitoneal space. The retroperitoneal space is a potential space within the abdominal cavity behind the peritoneum containing kidneys, ureters, aorta, IVC, pancreas, ascending & descending colon. It is rarely seen but is always abnormal.This condition is most frequently the result of bowel perforation caused by inflammatory disease (e.g., ruptured appendix), ulcerative disease (e.g., Crohn disease), iatrogenic (e.g., sigmoidoscopy, ERCP), or foreign body.[4,10]

Abnormal air in retroperitoneal space makes an appearance as a streaky/linear opacity outlining extraperitoneal structures or mottled/blotchy appearance. The position is relatively fixed and moving only a little with position changes. Extraperitoneal air may outline extraperitoneal structures, such as psoas muscles, kidneys, uterus, urinary bladder, and aorta (Figure 23 and 24).The size of the crescent will be roughly proportional to the amount of free air. The larger amount of free air, the larger the crescent. Free air is easier to recognize under the right hemidiaphragm because there is usually only the soft tissue density of the liver in that location and more difficult to recognize under the left hemidiaphragm because air-containing structures, like the fundus of the stomach and the splenic flexure, already reside in that location and may be mistaken for free air.Extraperitoneal air may extend through a diaphragmatic hiatus into the mediastinum, causing

pneumomediastinum or extending to the peritoneum.[4]

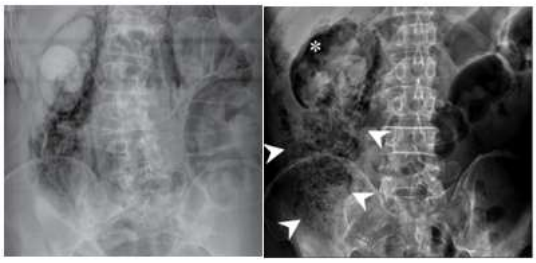

Figure 23 (Left)[10]& Figure 24 (Right)[17]Abnormal air in the retroperitoneal space makes appearance as a streaky/linear opacity outlining extraperitoneal structures or mottled/blotchy appearance (arrow). Extraperitoneal air may outline extraperitoneal structures, such as psoas muscles, kidneys (asterisk), uterus, urinary bladder, and aorta.[4]

PNEUMATOSIS INTESTINALIS

Pneumatosis intestinalis is a rare condition where there is a presence of gas within the intestinewall, primarily found in the colon (47%), followed by small bowel (27%), both the colon and small bowel (7%), stomach (5%), and the entire intestinal tract with portal venous gas (14%). The patients are usually asymptomatic but some patients may have mild abdominal discomfort, which is usually related to underlying associated medical conditions.[13,14] The causes are divided into a rare primary form called pneumatosis cystoides intestinalis and a more common secondary form that can occur, from COPD, NEC, Hirschsprung's disease, pyloric stenosis, or obstructing carcinoma.[4]

Air in the bowel wall is most easily recognized on abdominal radiographs when it is seen in profile producing a linear radiolucency (black line) whose contour exactly parallels with the bowel lumen (Figure 25).[4]From en face, it is more difficult to recognize but frequently has a mottled appearance that resembles gas mixed with fecal material. The appearance of the mottled gas pattern is relatively unchanged from different positions. Another appearance is globular, cyst-like collections of air paralleling with the contour of the bowel.[4]

PNEUMOBILIA & PORTAL VENOUS GAS

Pneumobilia is the presence of air in the biliary tree. The main causes are ERCP/incompetent sphincter of Oddi (post spinchterectomy), external biliary drain insertion/biliary stent insertion, biliary-enteric connection (surgical anastomosis or spontaneous), and infection (emphysematous cholecystitis).[10]

Portal venous gas is the accumulation of gas in the portal vein and its branches. In adults, it is indicating serious intraabdominal pathology and is associated with a very high mortality rate. In infants, it is a finding of far less consequence. The main causes of gas in the portal vein are ischemic bowel (most common), necrotizing enterocolitis (most common in infants), and severe intraabdominal sepsis (diverticulitis, pelvic abscess, appendicitis).[10]

Pneumobilia is seen in the center (hilum) of the liver (Figure 26). Sometimes, gas can also be seen in the common bile duct. Portal venous gas is seen in the periphery of the liver because blood in the portal vein flows from the center towards the periphery (Figure 27).[10]

Figure 25 (Right) Air in the bowel wall is most easily recognized on abdominal radiographs when it is seen in profile producing a linear radiolucency (black line) whose contour exactly parallels with the bowel lumen.[4] Figure 26 (Top Left) Pneumobilia: Branching dark lines (gas) are projected over the center of the liver, larger, and more prominent towards the hilum.[10] Figure 27 (Bottom Left)

Portal venous gas: Branching dark lines (gas) are projected over the periphery of the liver. In this case, the large amount of gas can be seen extending from the periphery to the center of the liver and extending to splenic vein.[(10)]

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