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Hidden Killers: The Plain Film Findings You Can't Afford to Miss

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Introduction

The United States has seen an exponential increase in the number of CT scans being performed over the last decade. At times it seems as if almost every Emergency Department patient is getting scanned for one indication or another. Rao et al looked at overall emergency department CT utilization among Medicare recipients and found a 227% increase from 2000-2008. These numbers might suggest that plain radiography has a diminished role in the care of the emergency patient. However, a careful examination of the utilization of different imaging modalities reveals that plain radiography still represents 65% of imaging studies obtained in the ED, vs. CT (29%) and ultrasound (4%).[1] There is still a definite role for plain radiography in the ED, and it is imperative that emergency practitioners be facile in interpreting these studies for a number of reasons.

Plain radiography is one of the initial screening tests performed in a variety of patient presentations. It is fast, relatively inexpensive, and can be performed portably in the case of an unstable patient. Many potentially catastrophic disease processes have characteristic findings on plain film, and early detection with radiographs can be potentially life-saving. These findings can be subtle, however, and emergency practitioners must have a thorough knowledge of their appearance and of their significance. Many ED's across the country do not have 24/7 radiology coverage, and the emergency physician is responsible for the initial interpretation and instituting treatment based on that interpretation. It is also critical to understand the limitations of plain radiography, and to know when more advanced imaging techniques are appropriate.

The following is a case-based review of some of the most potentially life-threatening diagnoses, demonstrating the characteristic findings on plain radiographs as well as the common pitfalls associated with interpretation of these studies.

Case #1: Chest Pain

D.R., a 45 year-old male, presented with sudden-onset chest pain which he described as "stabbing." On physical exam he was noted to be tachycardic with a heart rate of 115 bpm and hypertensive with a blood pressure of 185/75 mm Hg. His electrocardiogram revealed ST elevations in his inferior leads. A stat portable chest x-ray was performed, and the patient was taken emergently to the cardiac catheterization lab. His radiograph is shown below (Figure 1):

Figure 1

An aortogram performed during the catheterization revealed a dilated aortic root and a question of an intimal flap. The procedure was aborted and the patient was taken for emergent CT of the chest, which confirmed a Stanford Type A dissection with involvement of the descending aorta (Figure 2).

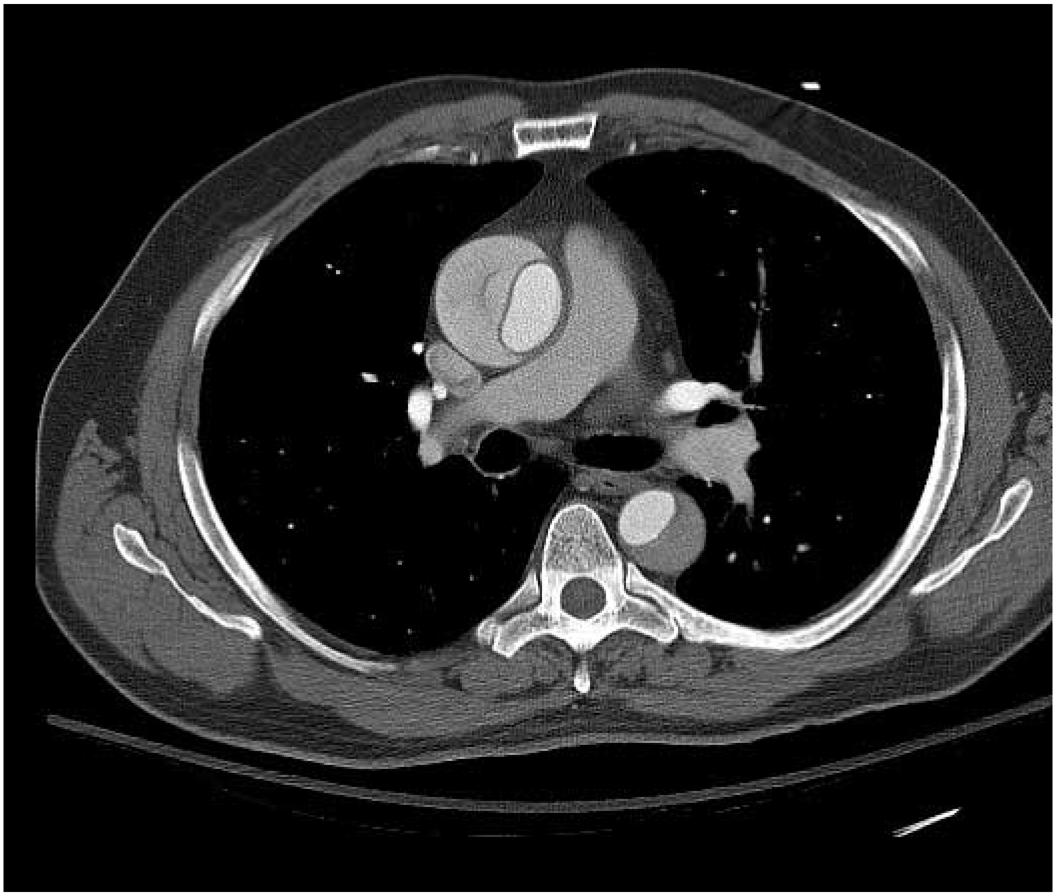

Figure 2

Classic teaching regarding aortic dissection is to look for a widened mediastinum or abnormal aortic contour on chest x-ray. This is a common misconception, which should be clarified. A review of the International Registry of Acute Aortic Dissections (IRAD) database revealed that mediastinal widening was present in only 63% of Type A dissections, and only 56% of Type B dissections.[2] Other studies looking at the sensitivity of an abnormal aortic contour revealed sensitivities of only 69-71%.[3,4] These findings make sense when one considers that true aortic dissection is primarily an intraluminal event that does little to *acutely* change the external diameter of the aorta. The cases where mediastinal widening or a dilated aortic contour are present are generally due to chronic degeneration of the aorta which occurs with aging. Therefore, it is a more common finding in older patients or those with aortic valvular disease. In younger patients the finding of an abnormal aortic contour should raise more suspicion for dissection.

Careful review of our patient's initial chest radiograph reveals a subtly abnormal convexity of the ascending aorta which was not appreciated on the initial interpretation (Figure 3, see arrows below). In retrospect, this prominence should not have been present in an otherwise healthy 45 year-old.

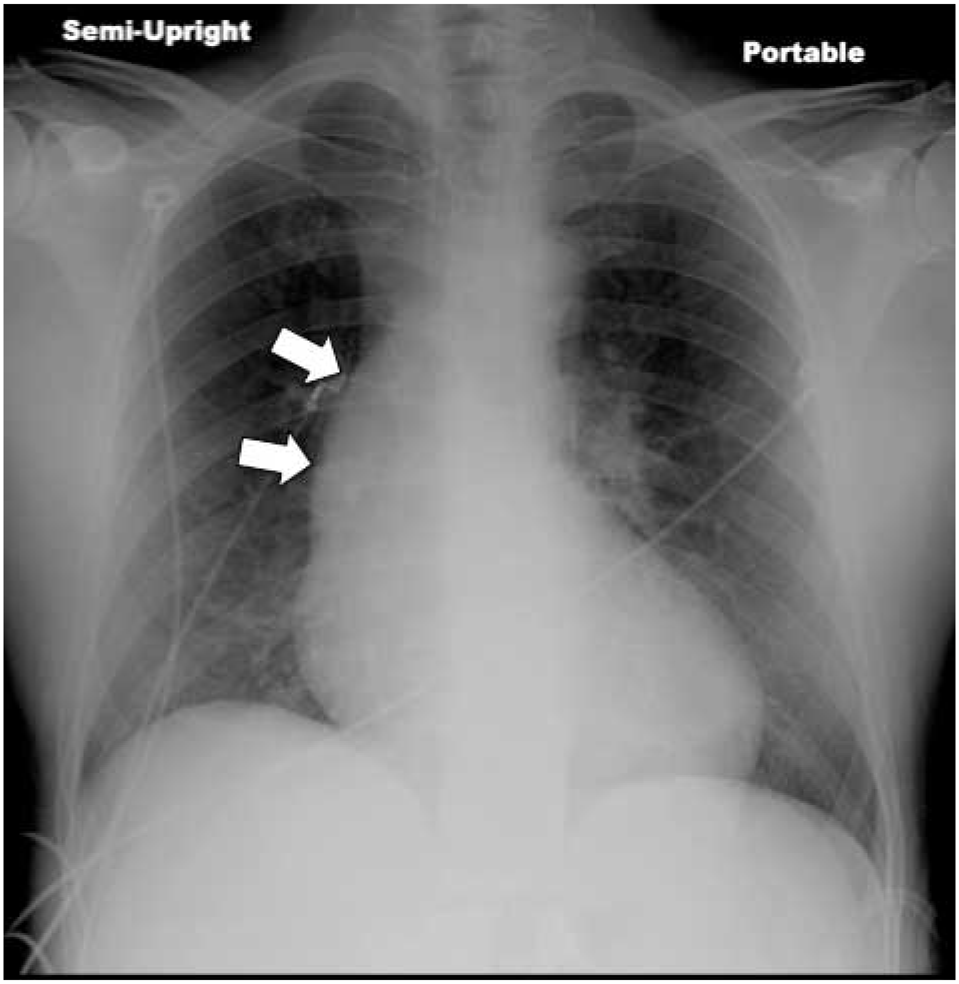

Figure 3

Figure 4 shows another example of an enlarged ascending aorta (white arrows) and dilated descending aorta (black arrows). This patient was a 65 year-old male presenting with ripping chest and back pain, and the official interpretation of the radiograph was "tortuous aorta." No prior radiographs were available for comparison. CT scan revealed an extensive Type A dissection.

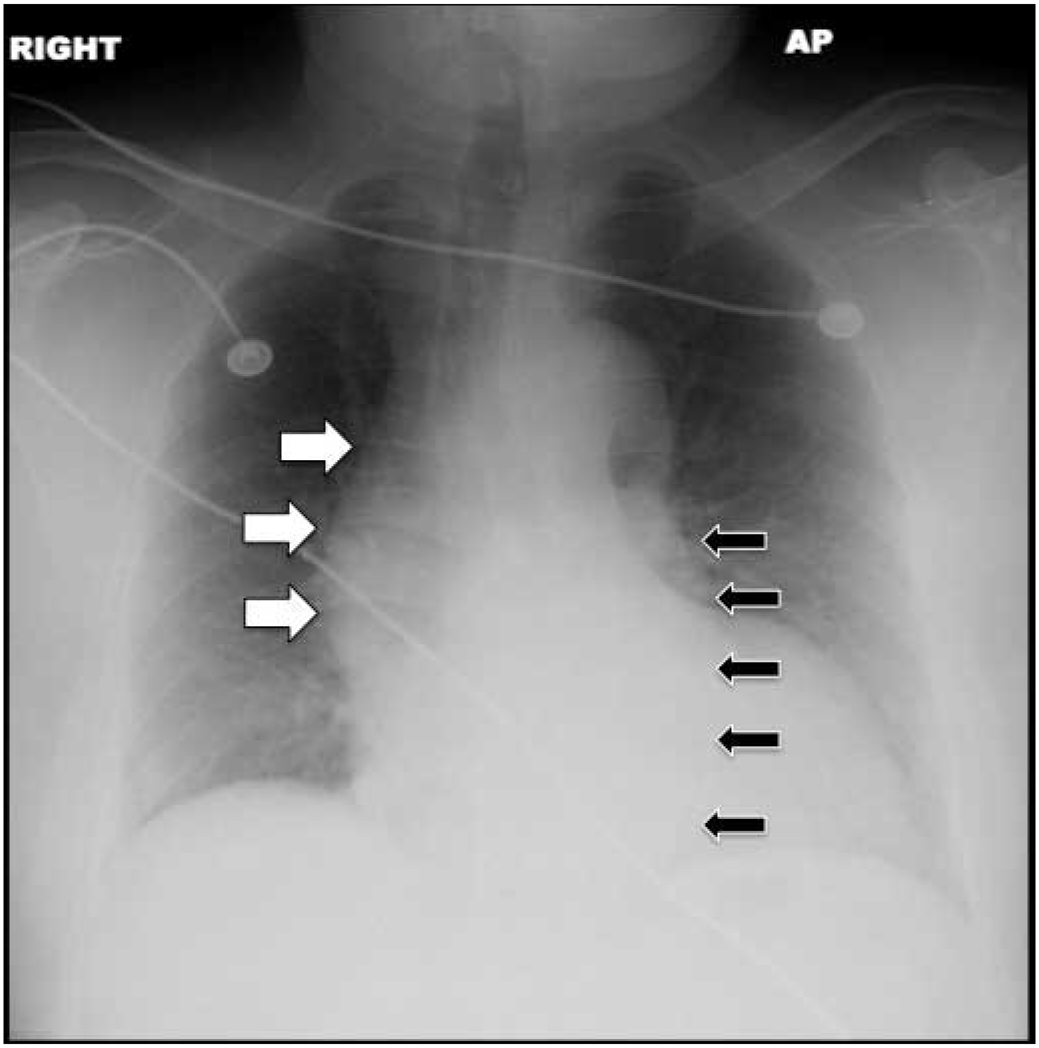

Figure 4

Another radiographic finding in aortic dissection is displacement of the calcified intima into the aortic lumen. It is an uncommon finding but is considered to be the most specific radiographic finding.[4,5] Below is an image of a displaced intimal calcification (Figure 5, arrows) in a patient presenting in heart failure due to acute valvular incompetence from a Type A dissection.

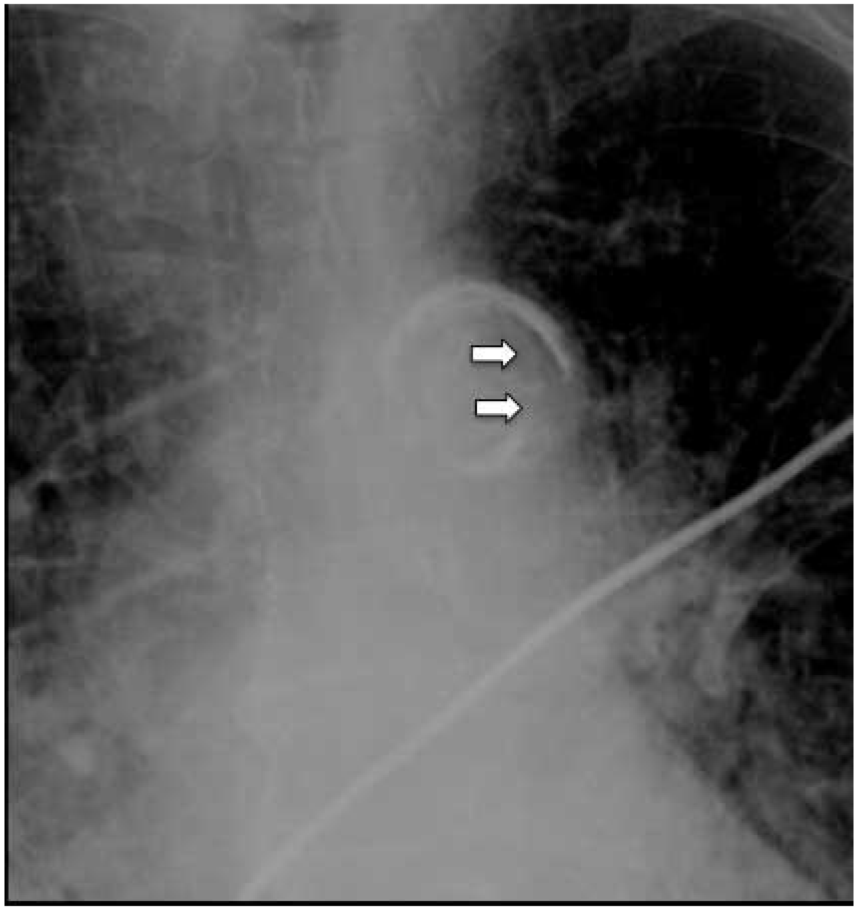

Figure 5

Of note, review of the IRAD database revealed that 11-15% of chest radiographs were interpreted as normal, and the abnormalities noted were often non-specific findings. For instance, the incidence of pleural effusions was 19%.[2] This underscores the importance of obtaining a good history and physical exam, and maintaining a high index of suspicion for this potentially devastating disease even with relatively normal radiographs. A confirmatory test such as CT of the chest or transesophageal echocardiogram is required in all cases where suspicion exists for this entity.

Case #2: Motor vehicle accident

R.T., a 24 year-old male, was an unrestrained passenger whose vehicle was struck at high speed on the passenger's side. He was intoxicated and complaining of severe chest pain. On exam he was tachycardic with a heart rate of 125 bpm, hypotensive with a blood pressure of 92/56 mm Hg, and oxygen saturation of 92% on a 100% non-rebreather. A stat portable AP chest x-ray was obtained and is shown below (Figure 6).

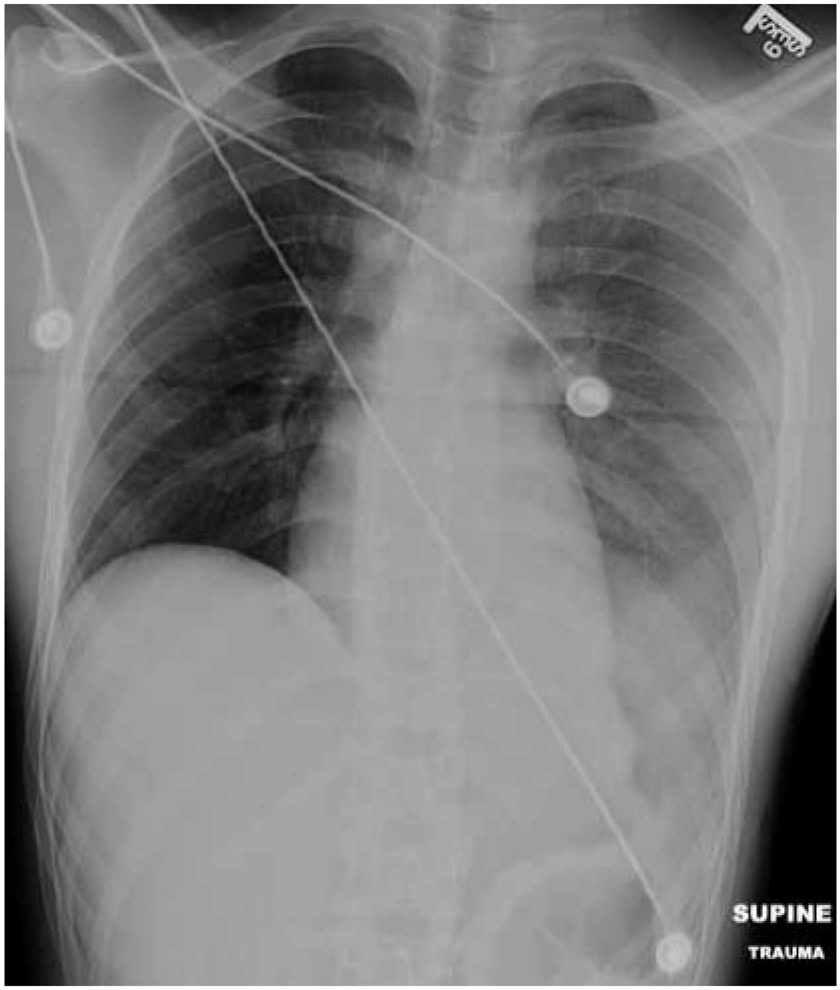

Figure 6

Review of the radiograph reveals an indistinct, plunging left hemi-diaphragm and hyperlucent left upper quadrant. This is classically referred to as a "deep sulcus sign," and may be the only finding of a pneumothorax in a supine patient. It is critical to evaluate the film technique when evaluating chest radiographs, as differences in technique can have drastic implications on interpretation. In a supine patient, air in the pleural space collects *anteromedially* and *basally*, rather than *apicolaterally* as in an upright patient. If it collects laterally it deepens the lateral costophrenic angle and produces the deep sulcus sign.[6] However, occasionally the air collects anteromedially and may produce an unusually sharp outline of the mediastinal vascular structures, heart border, and cardiophrenic sulcus. Careful review of the radiograph below (Figure 7) of a 60 year-old female who fell down 12 steps reveals an abnormally sharp right heart border (white arrows). The presence of a displaced rib fracture on the same side (black arrow) as well as an anterior humeral dislocation, should increase suspicion for lung injury. CT scan of the chest confirmed the presence of a small hemopneumothorax.

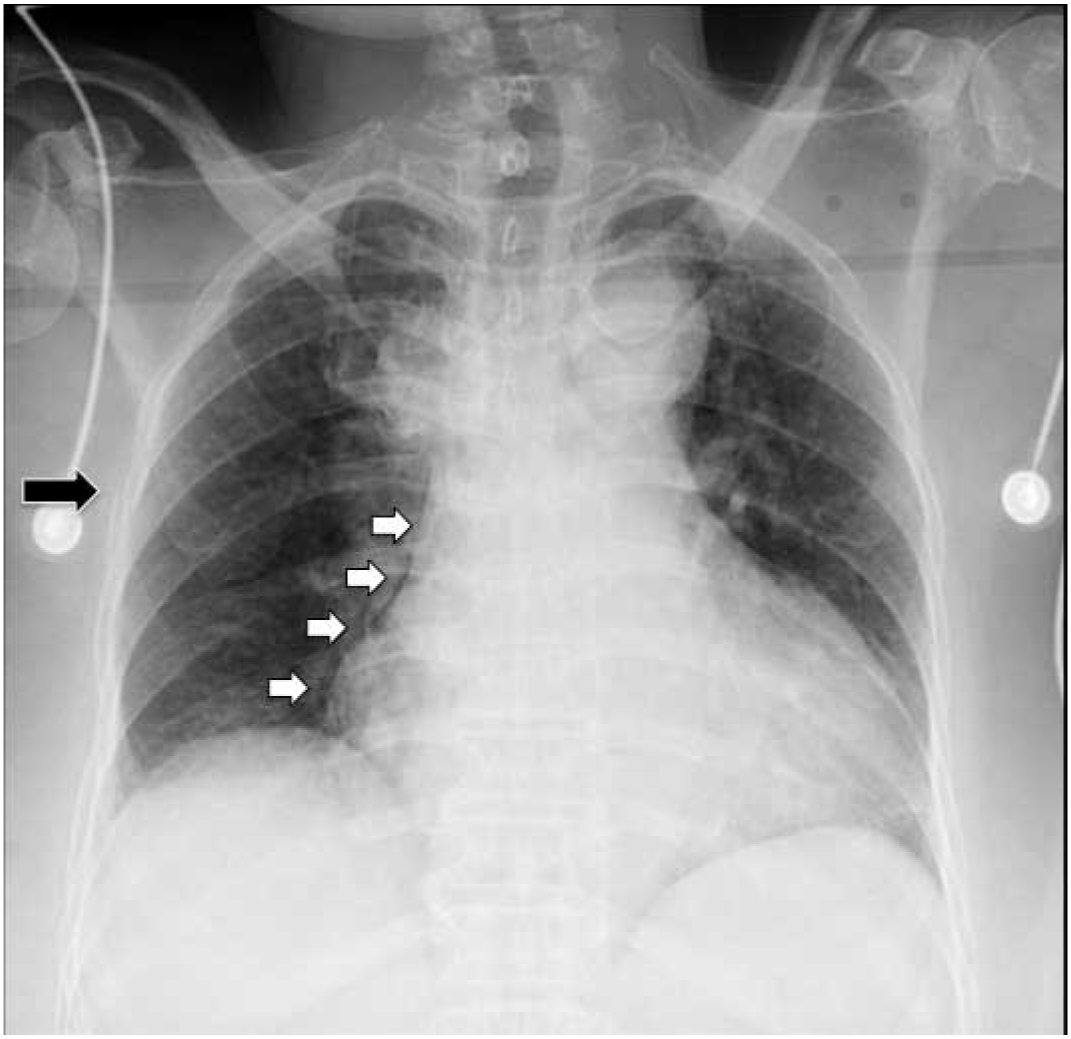

Figure 7

Other techniques for improving detection of a suspected pneumothorax on plain film, particularly in an upright patient, include expiratory views (Figure 8) which compress the thoracic structures and increase detection of the pleural reflection (arrows).

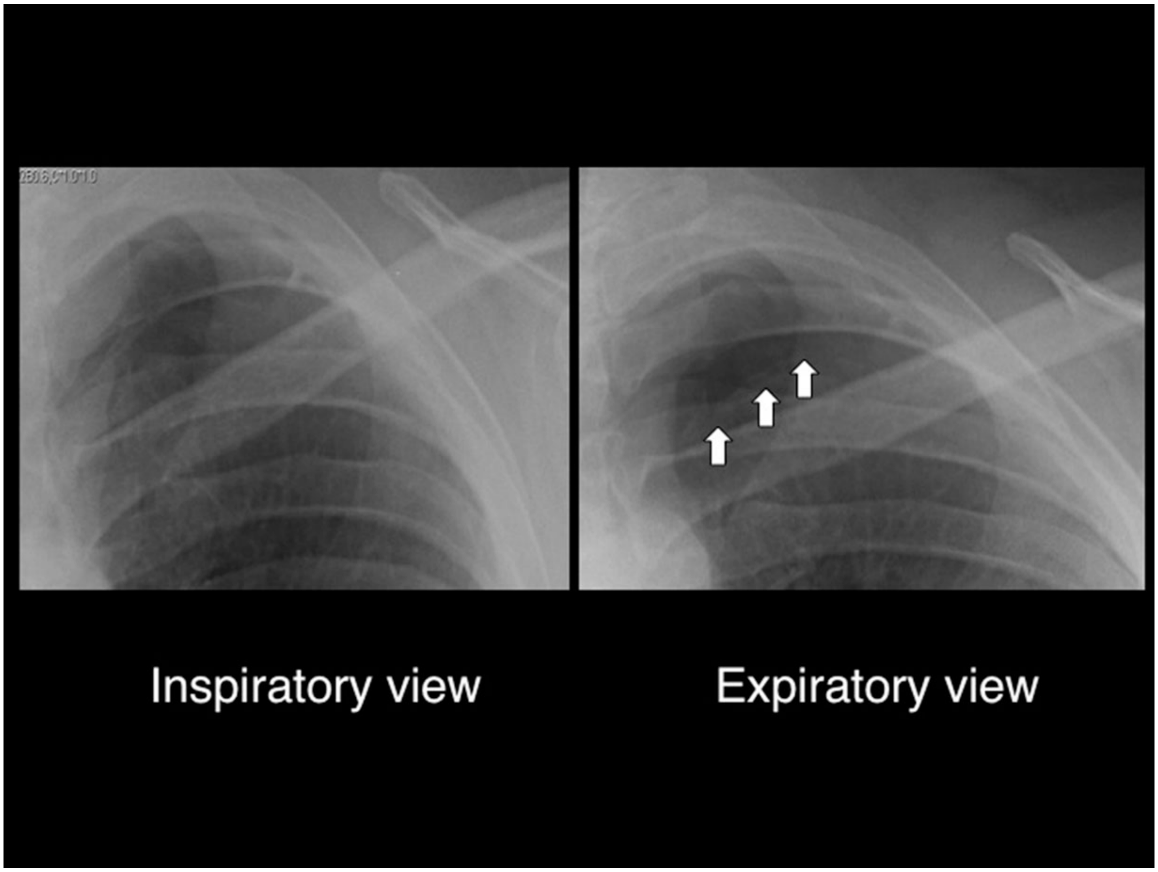

Figure 8

With digital radiography most clinicians have the ability to invert the image, which has a similar effect as using a hot light in the era of physical films to highlight the pleural reflection (Figure 9, arrows).

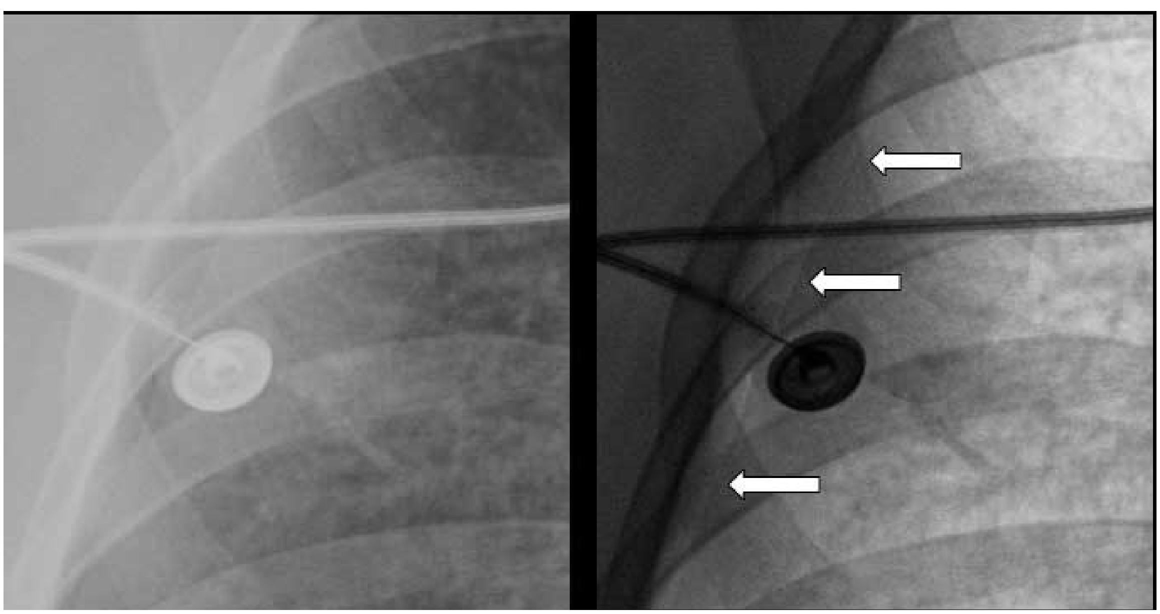

Figure 9

It is important to note that plain chest radiography is a relatively insensitive test for detection of pneumothorax. Standard upright chest x-ray has a sensitivity of only 59%, and supine AP radiographs only 37%.[7] Performing a lateral decubitus chest radiograph may increase sensitivity to 87%, although this is often not practical in the unstable trauma patient. When in doubt CT scan of the chest is the gold standard for detection of pneumothorax, although some studies suggest that thoracic ultrasound might be a viable alternative, with sensitivities ranging from 79-100% for detection of pneumothorax.[8-10] It is important to note that a small pneumothorax in the stable patient which is radiographically occult on plain film is unlikely to affect management, so CT scan should likely be reserved for unstable patients, those on positive-pressure ventilation, or for those in whom there is suspicion for other thoracic injuries.

Case #3: Bicycle Accident

C.R., a 32 year-old male, was thrown from a bicycle landing on his right side. He presented complaining of severe pleuritic right chest pain. On physical exam he was diffusely tender to palpation of his right chest and right upper quadrant. He was noted to be tachycardic with a heart rate of 115 bpm, respiratory rate of 24 breaths per minute, blood pressure of 150/95 mm Hg, and oxygen saturation was 98% on room air. A stat portable supine chest x-ray was obtained, and is shown below (Figure 10).

Figure 10

Upon first glance one might think that the patient has a large hemothorax on the right. However, it is critical to remember to carefully evaluate the film technique when interpreting a radiograph. On a supine film an acute effusion, such as a hemothorax in the trauma setting, will layer out posteriorly, causing the affected side to appear more opaque compared to the other side. In this case the opacity seen on the right is more concerning for abdominal contents, such as from a diaphragmatic rupture, even though those are rare on the right side. A CT scan performed on the patient confirmed that there were abdominal contents in the right hemithorax, most likely the result of a congenital diaphragmatic hernia (Figure 11). There were no signs of traumatic injury such as liver laceration, rib fractures, or free fluid.

Figure 11

In contrast, review the supine radiograph below (figure 12) of an unfortunate assault victim who was severely beaten with a baseball bat. In addition to multiple left-sided rib fractures and a deep sulcus sign on the left, careful comparison of the lung fields reveals increased opacity of the left lung. This is consistent with a hemothorax in a supine patient. The radiograph is also concerning for radiographic signs of tension pneumothorax with mediastinal shift to the right.

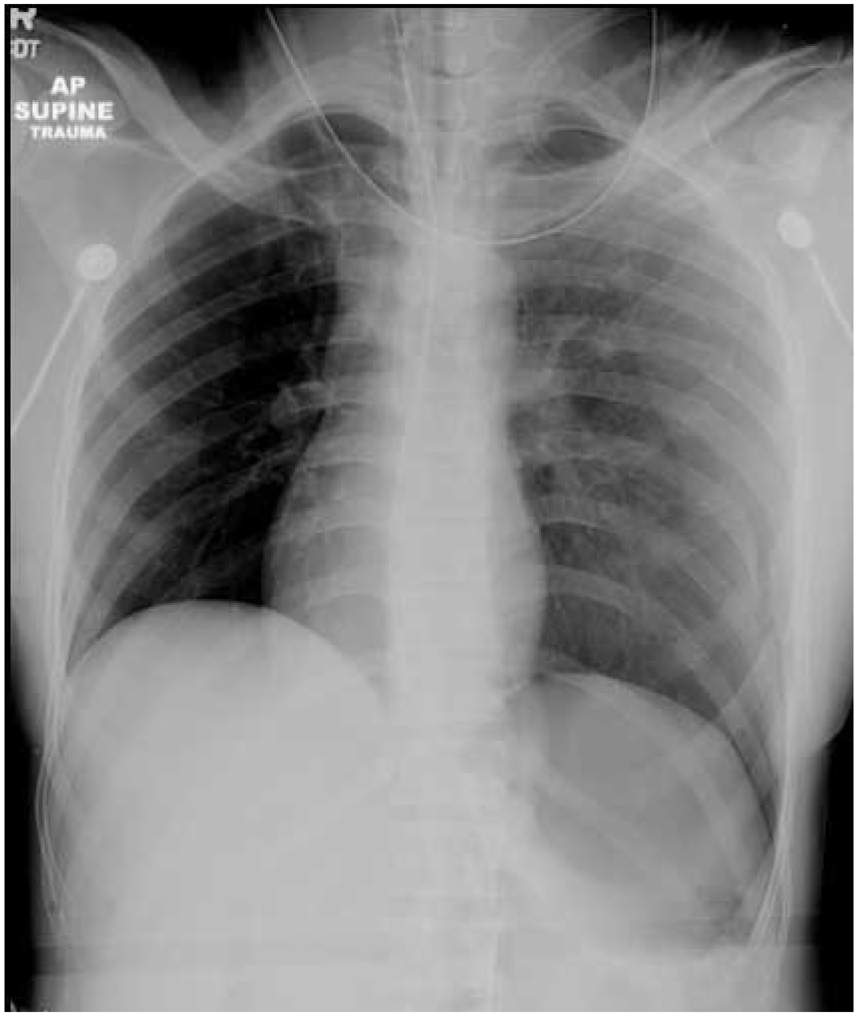

Figure 12

Figure 13 shows the contrast between a layering effusion on an upright radiograph (left) vs. a supine radiograph (right).

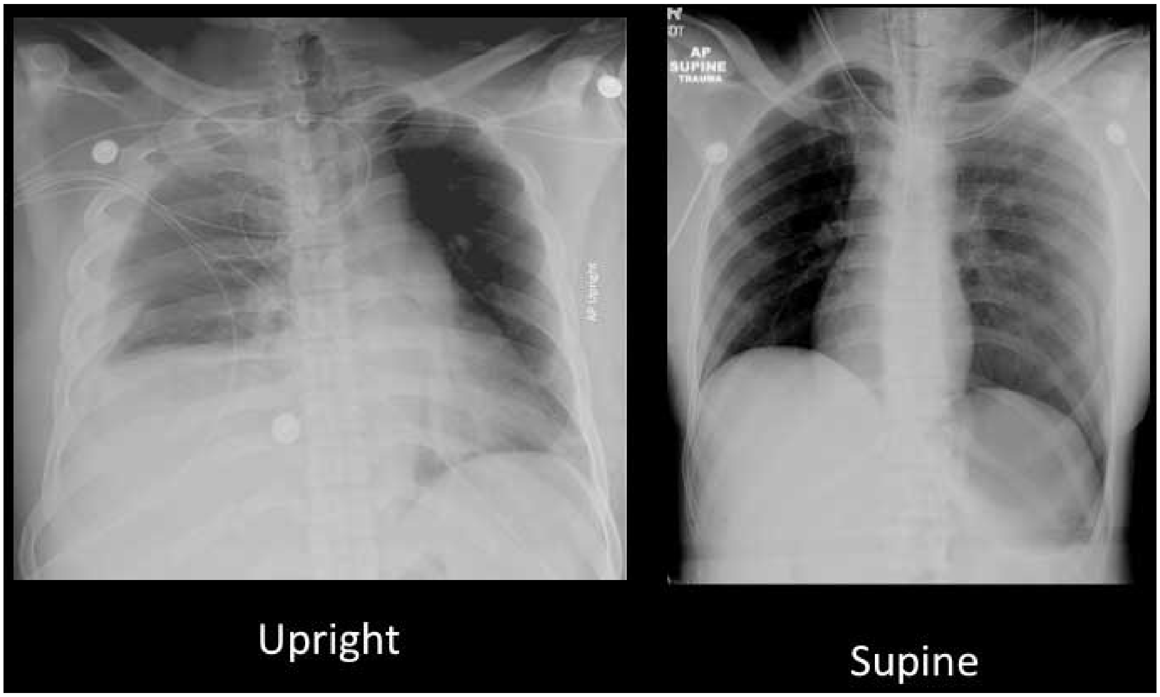

Figure 13

Case #4: Chest pain

D.B., a 27 year-old male, presented to the ED complaining of sudden onset severe, pleuritic chest pain. On physical examination the patient was noted to be uncomfortable, agitated, and tachycardic with a heart rate of 125 bpm. He was tachypneic but his oxygenation was normal. A PA and lateral chest series was obtained (Figure 14).

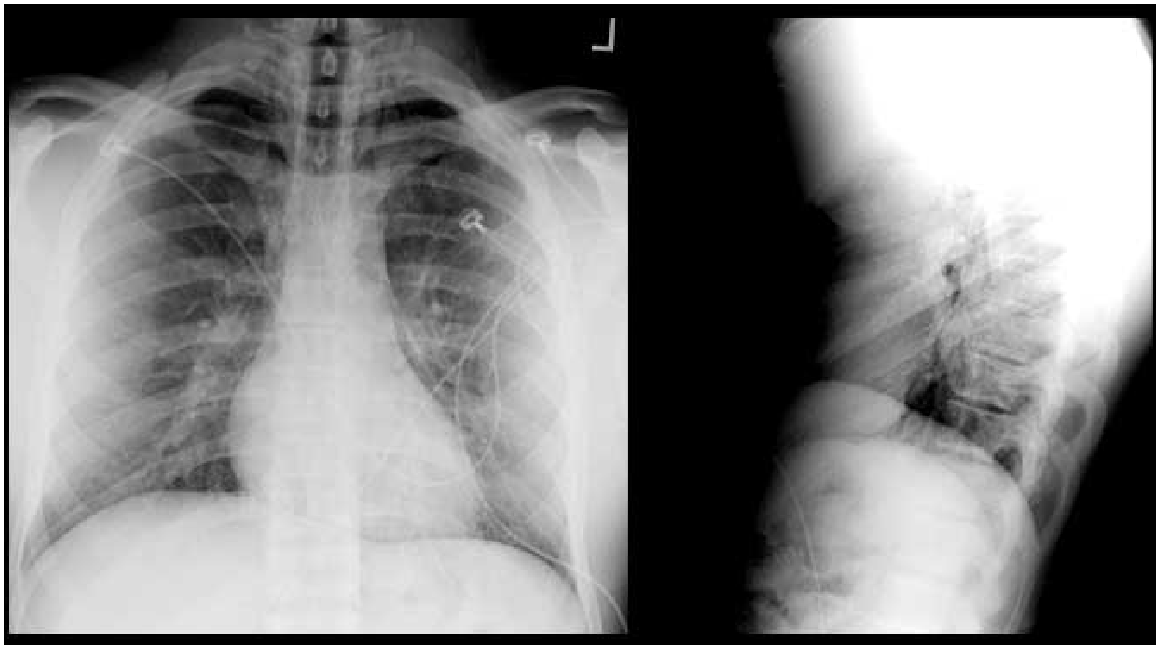

Figure 14

Careful examination of the PA radiograph reveals several abnormalities (Figure 15) consistent with pneumomediastinum.

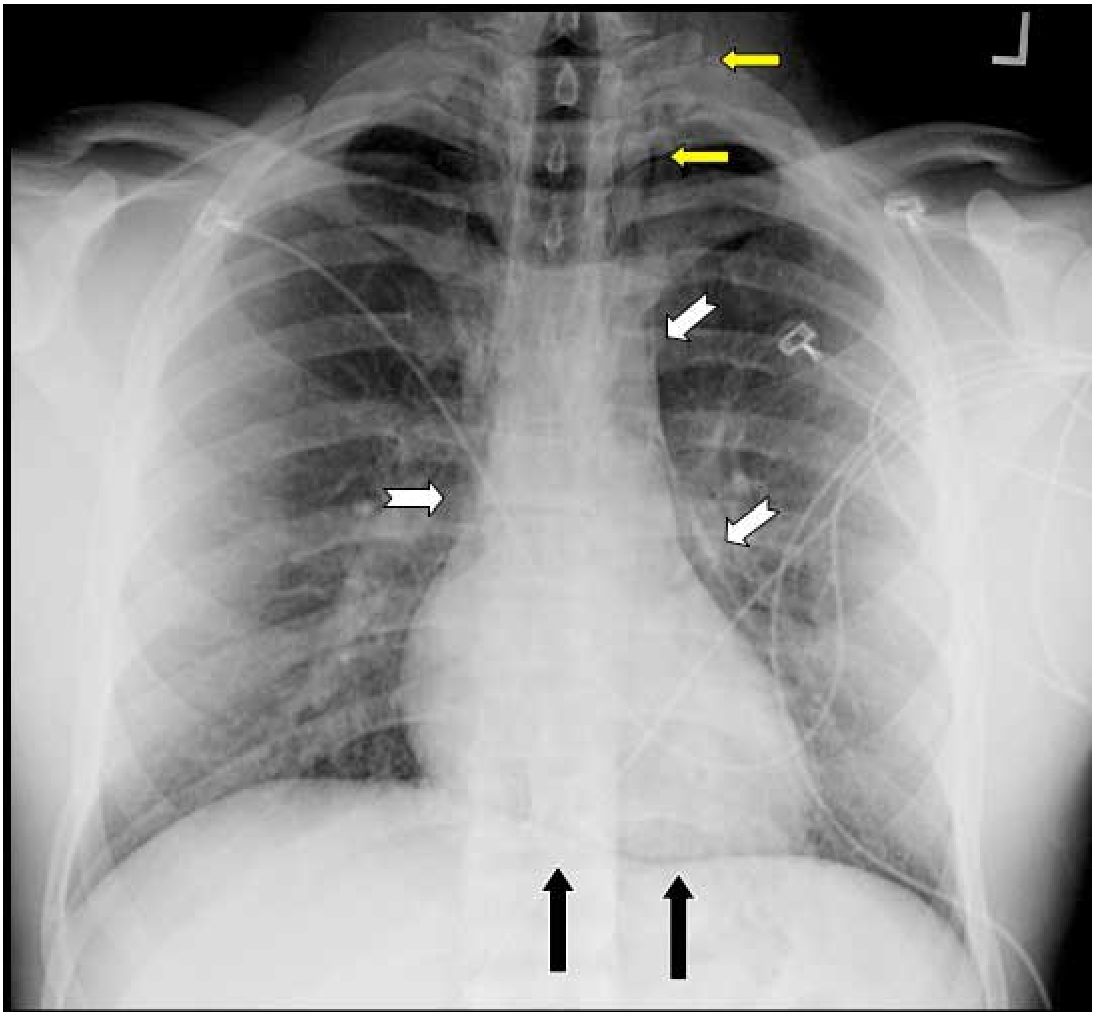

Figure 15

There is a thin layer of air between the heart and the adjacent pleural laterally, and the thin white pleura can be visualized (white arrows). There are also linear streaks of air tracking up into the superior mediastinum (yellow arrows). The lucency extending across the base of the heart between the heart and diaphragm (black arrows) is abnormal, and is termed the "continuous diaphragm sign." [11] Normally the heart is tightly apposed to the left hemidiaphragm, and one should not be able to trace the diaphragm across the mediastinal space. Review of the lateral film (Figure 16) reveals a similar finding, where one can clearly trace the left hemidiaphragm across (arrow) due to air interposed between the heart and the left hemidiaphragm.

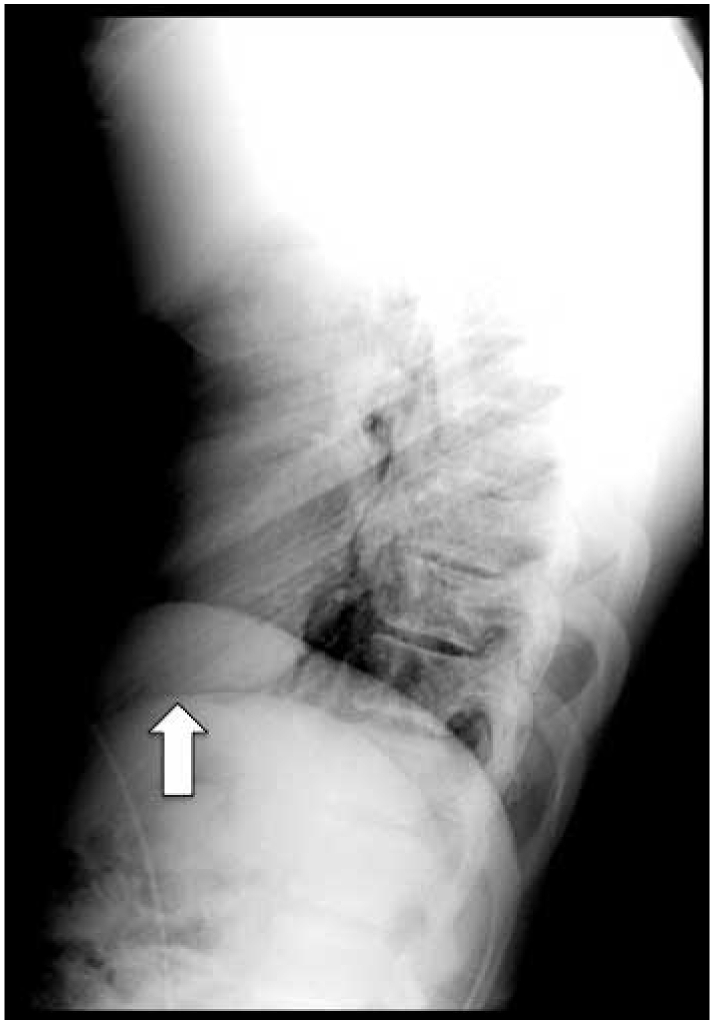

Figure 16

Other findings consistent with pneumomediastinum that may be seen on the lateral radiograph include air in the retrosternal space, as well as air outlining the origin of the right main pulmonary artery, known as the "ring around the artery" sign.[12]

Upon reviewing the findings on chest x-ray the patient was questioned further about the events leading up to the onset of his chest pain. After much prodding the patient admitted to smoking crack cocaine immediately prior to the onset of his chest pain. This is a common etiology of pneumomediastinum.[13,14] It is seen in cases where there is an increase in intra-thoracic pressure against a closed glottis. In addition to illicit drug use, it is commonly seen in asthmatics, weight lifters, and following blunt thoracic trauma. It generally has a benign course and rarely causes hemodynamic compromise from tension physiology, as the air often decompresses into the soft tissues of the neck and chest. However, it should be differentiated from pneumopericardium, which can have a somewhat similar appearance on radiographs but may have more severe clinical consequences such as tension pneumopericardium.

Below is an AP chest radiograph obtained in an infant who was intubated for respiratory distress (Figure 17).

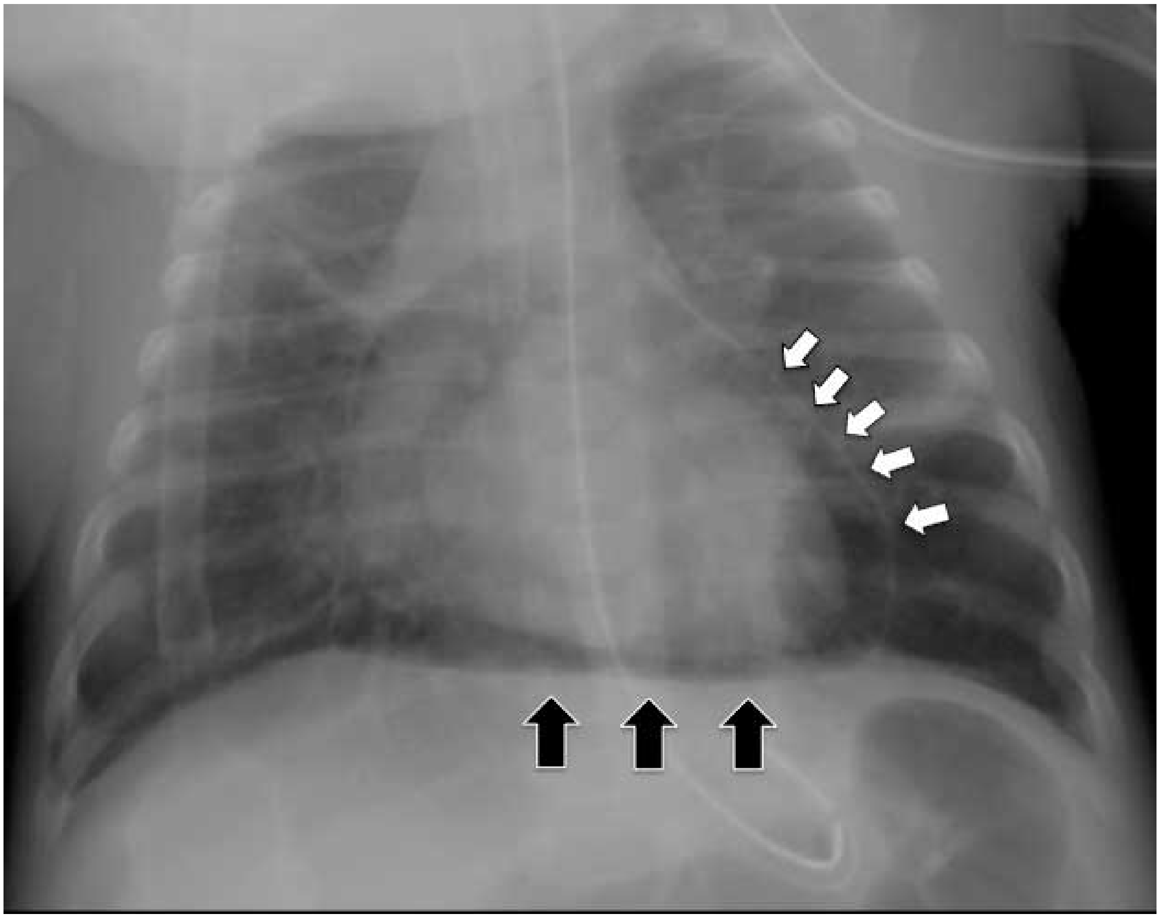

Figure 17

Initially the patient was hemodynamically stable, however he became abruptly hypotensive approximately one hour post-intubation. The providers were initially concerned for a tension pneumothorax, however the patient had equal breath sounds bilaterally. A stat x-ray was performed, and review of the radiograph revealed a continuous diaphragm sign (black arrows) and air interspersed between the heart and the pericardium (white arrows). One can sometimes differentiate between pericardium and parietal pleura on plain film since the pericardium is a thicker structure than pleura, and as such has a thicker white line on the radiograph. In addition, in pneumomediastinum the air often tracks into the superior mediastinum or neck, whereas air is confined to around the heart in pneumopericardium.

In addition to recognizing the oftentimes subtle radiographic signs of pneumomediastinum, it is important to realize that there may be false positives as well. In particular, artifact from hair or clothing can sometimes appear as linear streaking in the neck or upper mediastinum and appear very similar to true pneumomediastinum. Below is the PA radiograph of a 15 yo female presenting with chest pain (Figure 18):

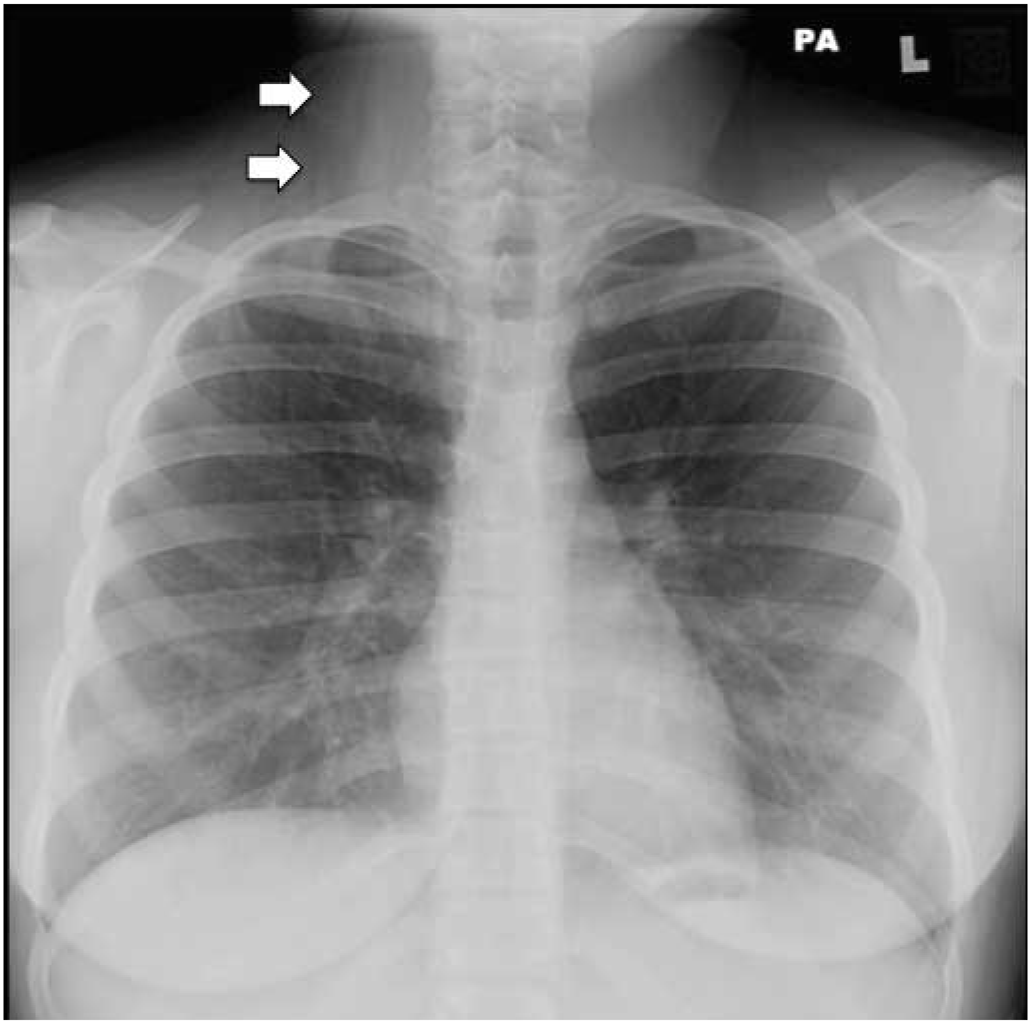

Figure 18

The linear streaking in the right neck soft tissues (arrows) was noted, and a diagnosis of pneumomediastinum was made. However, on exam the clinician noted that the patient had long hair in braids. Upon questioning the patient stated that she had not moved her hair while taking the chest x-ray. Her hair was pulled back, and she was taken back for repeat radiographs. Figure 19 below, taken approximately 20 minutes after the first x-ray, shows complete resolution of the linear lucencies.

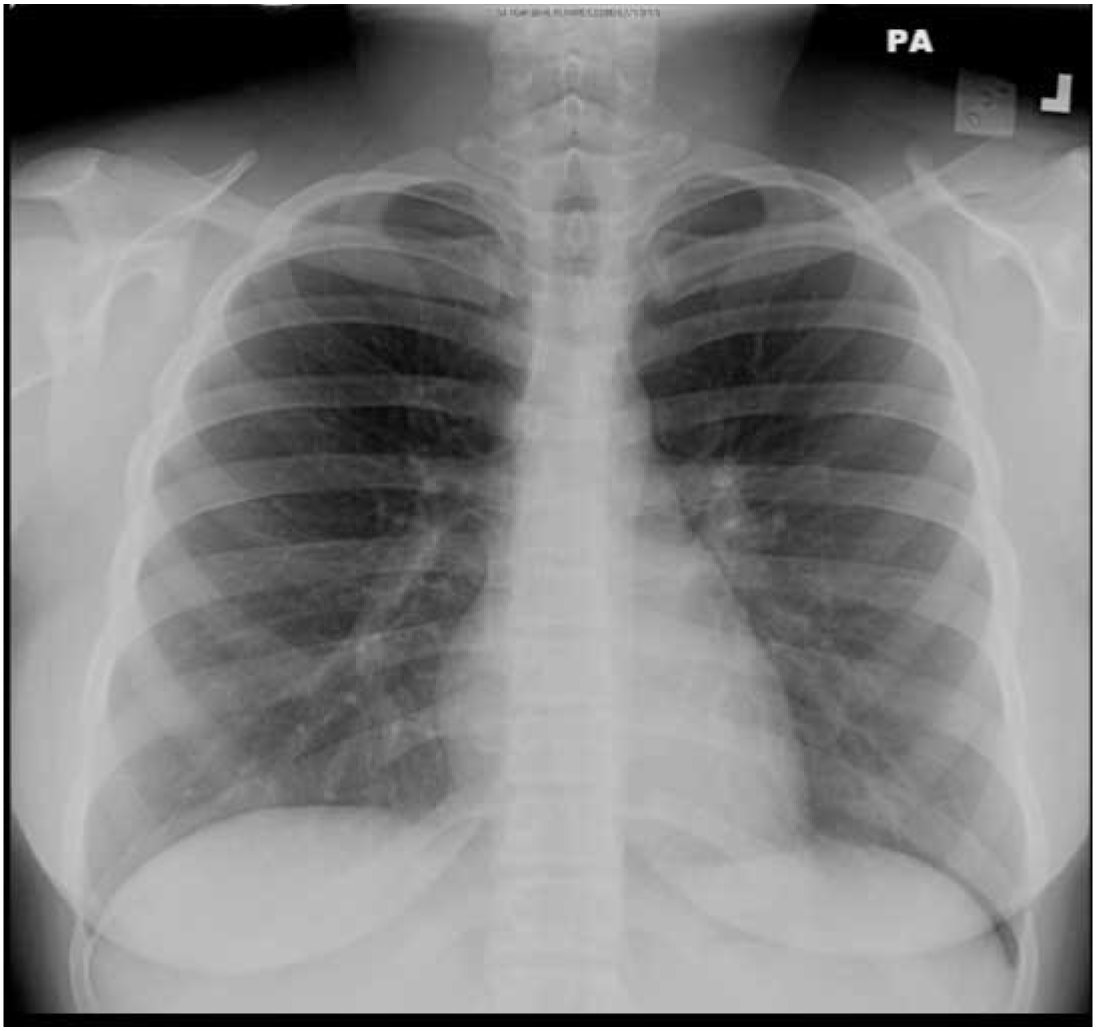

Figure 19

Case #5: Alcohol intoxication

R.S., a 50 year-old male, presented from a homeless shelter with alcohol intoxication. During EMS transport he began to vomit profusely. On physical exam he was clinically intoxicated with slurred speech, and was complaining of chest pain. His vitals signs were notable for a heart rate of 120 bpm, a respiratory rate of 22, and oxygen saturations of 92% on room air. A stat portable chest radiograph was obtained, and is shown below (Figure 20):

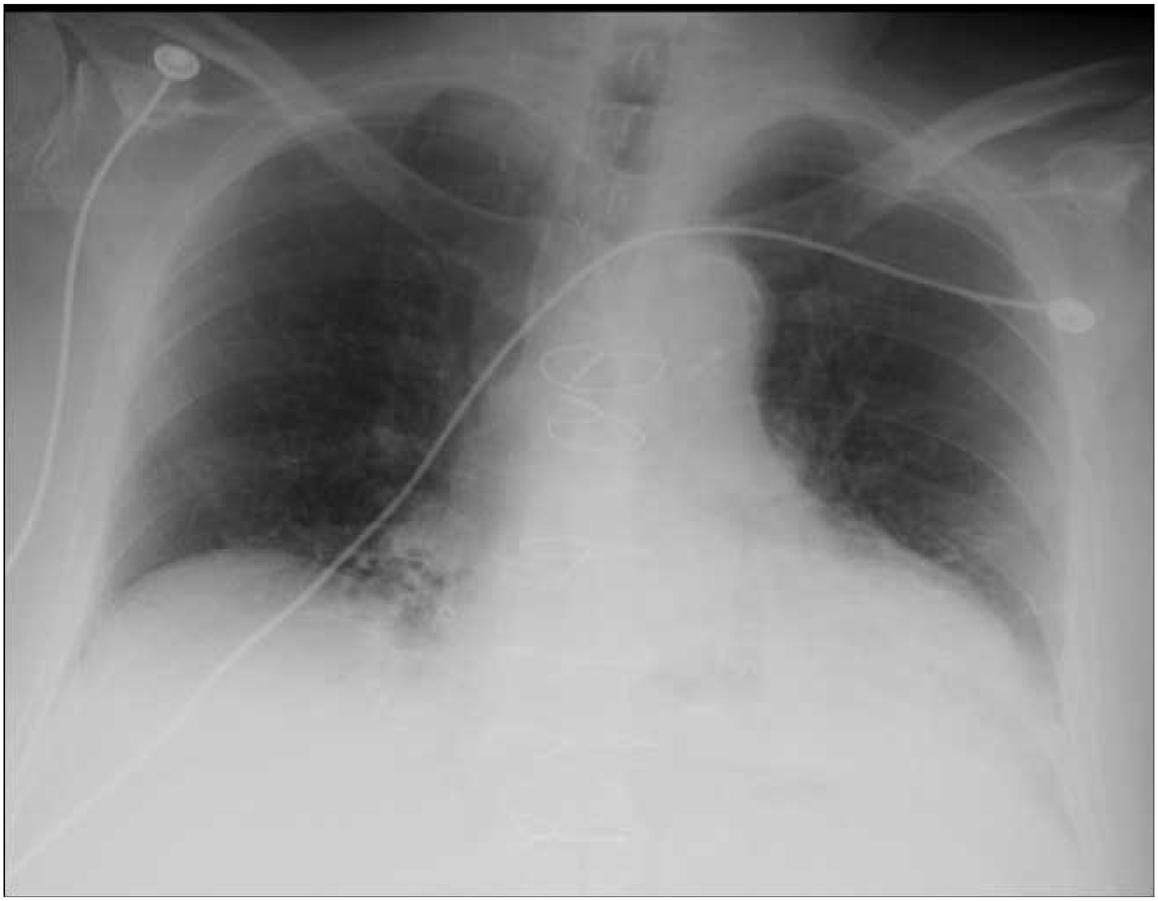

Figure 20

The radiograph was initially interpreted as probable bibasilar airspace disease, with an opacity noted at the right cardiophrenic sulcus as well as a retrocardiac infiltrate on the left. A lateral was not performed given the patient's intoxicated state. It was decided that the patient likely aspirated during his episodes of vomiting, and given his history of alcoholism and poor social situation the decision was made to admit the patient. During the initial day of his hospitalization he complained of increasing chest pain, shortness of breath, and began spiking a fever. His oxygen saturations also continued to drop. A CT scan of the chest was performed and a representative slice is shown below (Figure 21):

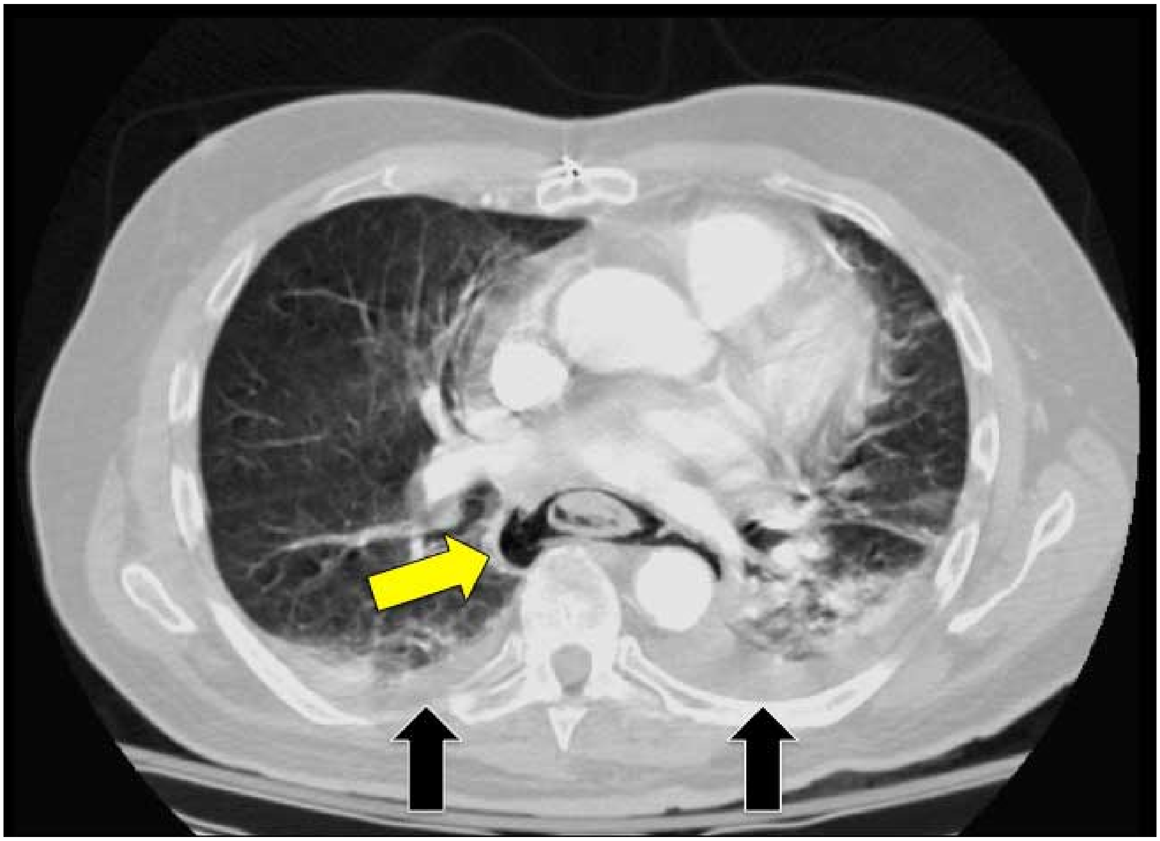

Figure 21

The CT reveals air outlining the esophagus (yellow arrow) as well as bilateral pleural effusions (black arrows), left greater than right. The patient was diagnosed with Boerhaave's syndrome, and was started on broad-spectrum antibiotics. He went to the operating room for debridement, but had a complicated post-operative course and died approximately one week after his initial presentation from sepsis.

In retrospect, review of the patient's initial radiograph (Figure 22) reveals that the right airspace "opacity" was really loculated air adjacent to the esophagus (white arrow).

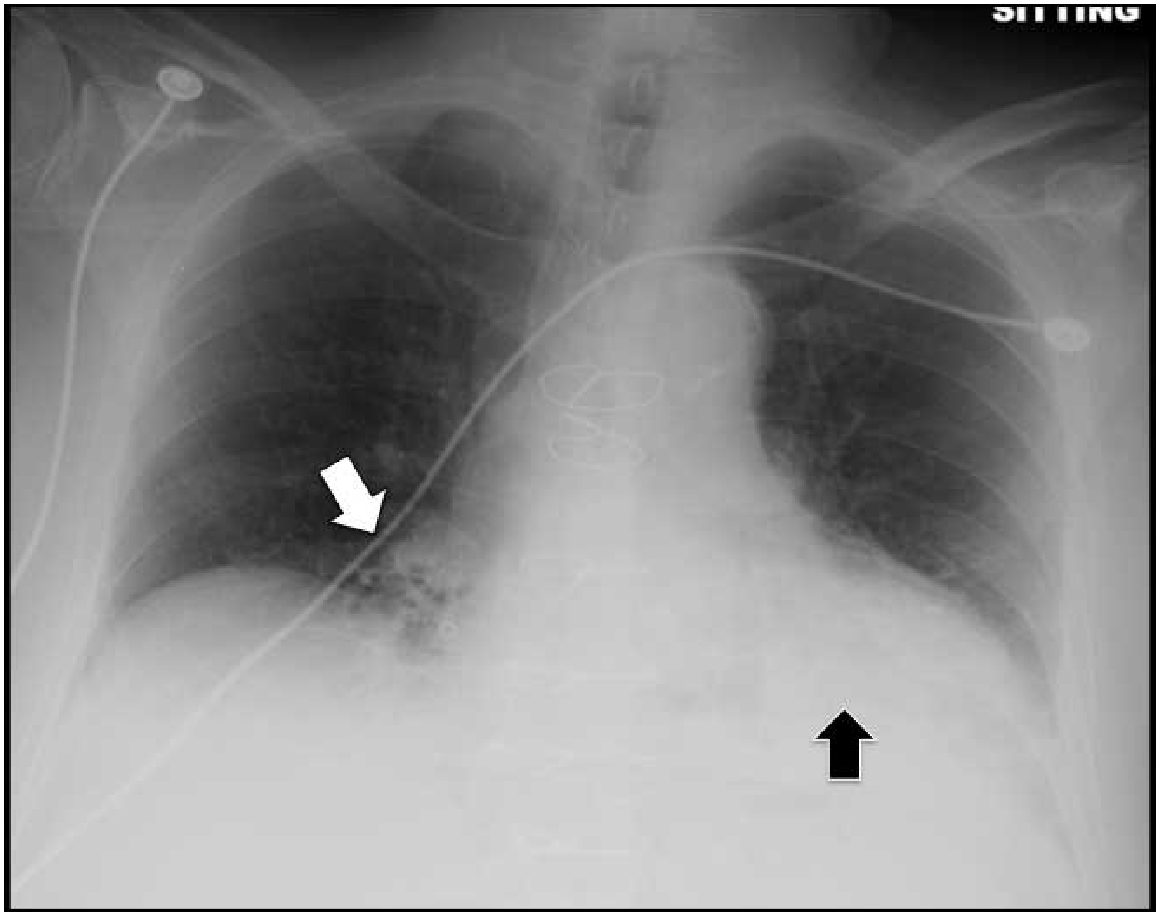

Figure 22

The left “basilar airspace disease,” manifested by an inability to trace out the left hemidiaphragm behind the heart, was in reality of small pleural effusion (black arrow). This would have been more apparent on a lateral radiograph. It is critical for the emergency practitioner to appreciate the various appearances of pneumomediastinum, and to realize the clinical significance when seen with a pleural effusion. The majority of cases of effort-related esophageal rupture (Boerhaave’s syndrome) occur at the left posterolateral aspect of the distal esophagus, and commonly cause a pleural effusion, usually left-sided.[15,16] It is also important to note that in one series a history of alcohol was present in 40% of cases of Boerhaave’s syndrome, and as such should be suspected in all intoxicated patients who are presenting with chest pain after vomiting.[17]

Case #6: Chest pain

L.B. , a 50 year-old obese female, presented complaining of rapid onset of left-sided sharp, pleuritic chest pain and shortness of breath. On physical examination she was afebrile, tachycardic with a heart rate of 125 bpm, tachypneic with a respiratory rate of 26, and was saturating 93% on room air. A stat PA and lateral chest radiograph were obtained, and are shown below (Figures 23 and 24):

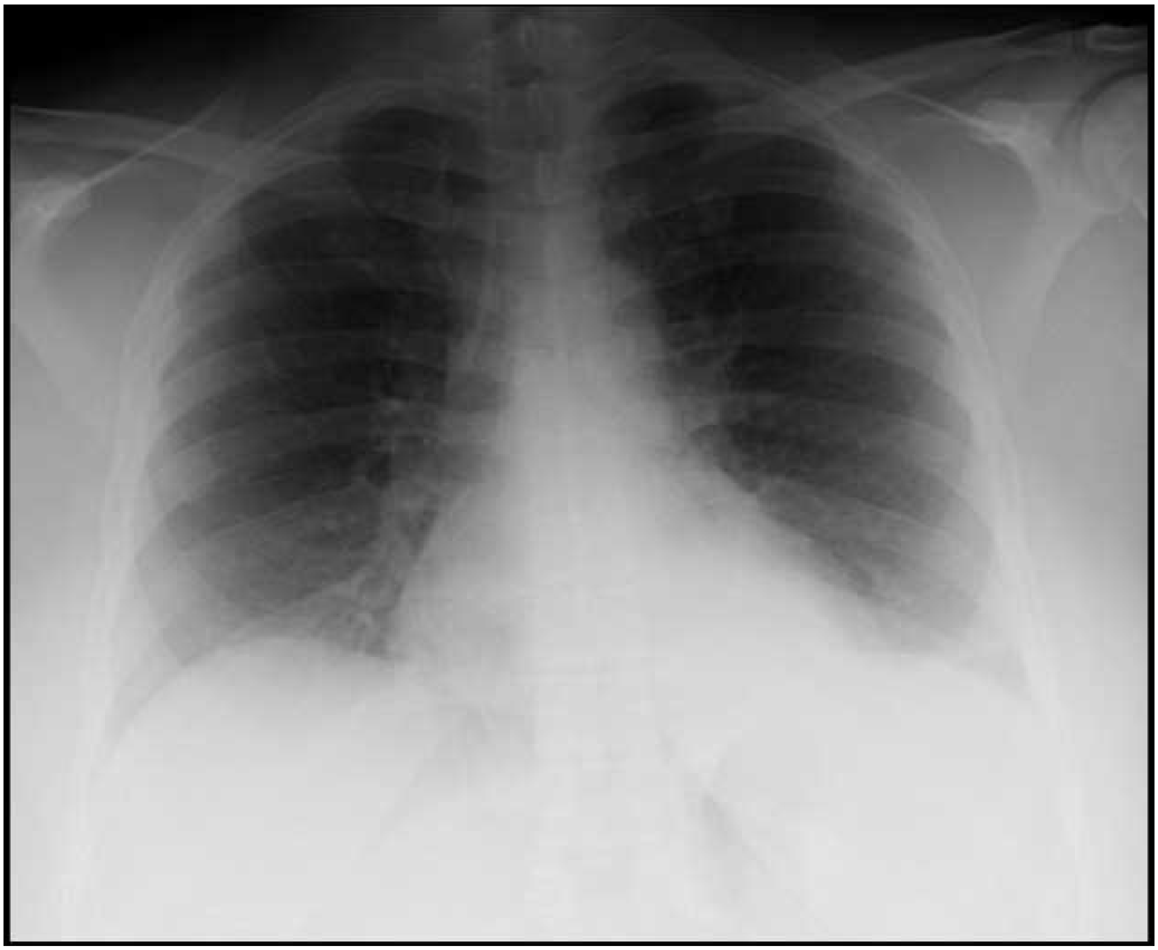

Figure 23

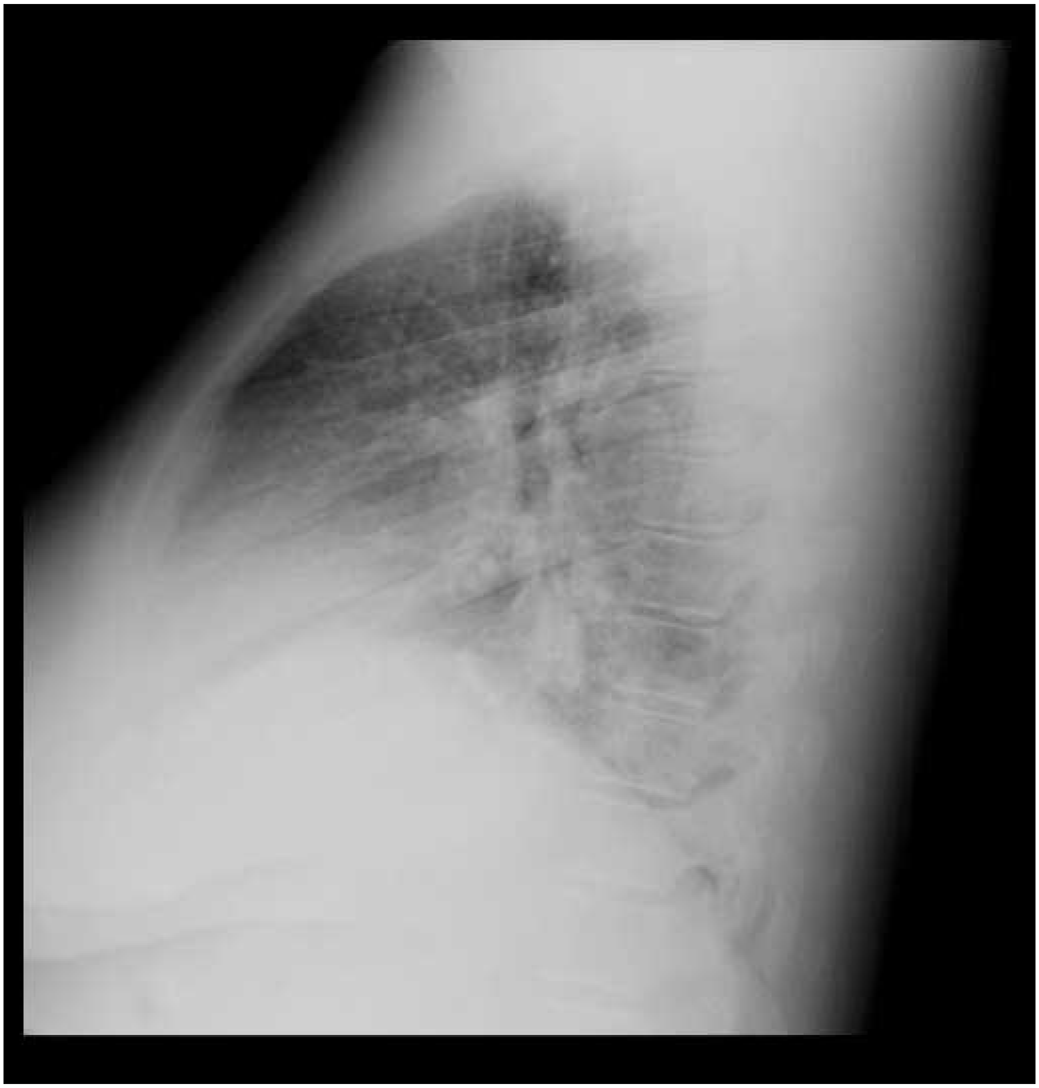

Figure 24

The official interpretation by the radiologist was "Limited by body habitus, question of a retrocardiac infiltrate." Given the dramatic clinical presentation and the woman's overall distress, coupled with the equivocal plain film findings, a CTA of the chest was performed. A representative slice is shown below, revealing a large, dense, left lower lobe consolidation (Figure 25, arrow).

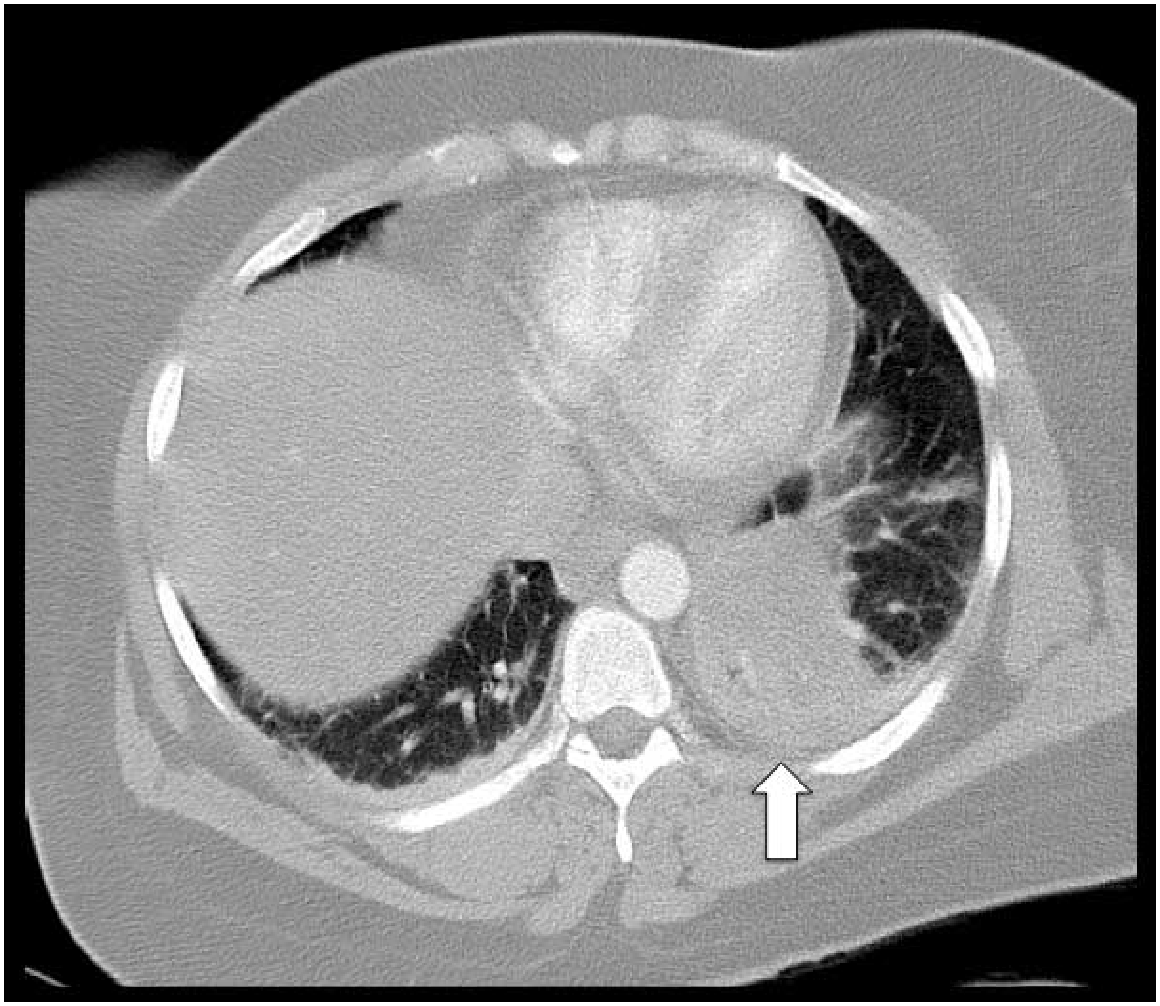

Figure 25

Upon review of the patient's radiographs from 2 years prior one is clearly able to trace out the left hemidiaphragm behind the heart on the PA view, even given the patient's body habitus (Figure 26, right).

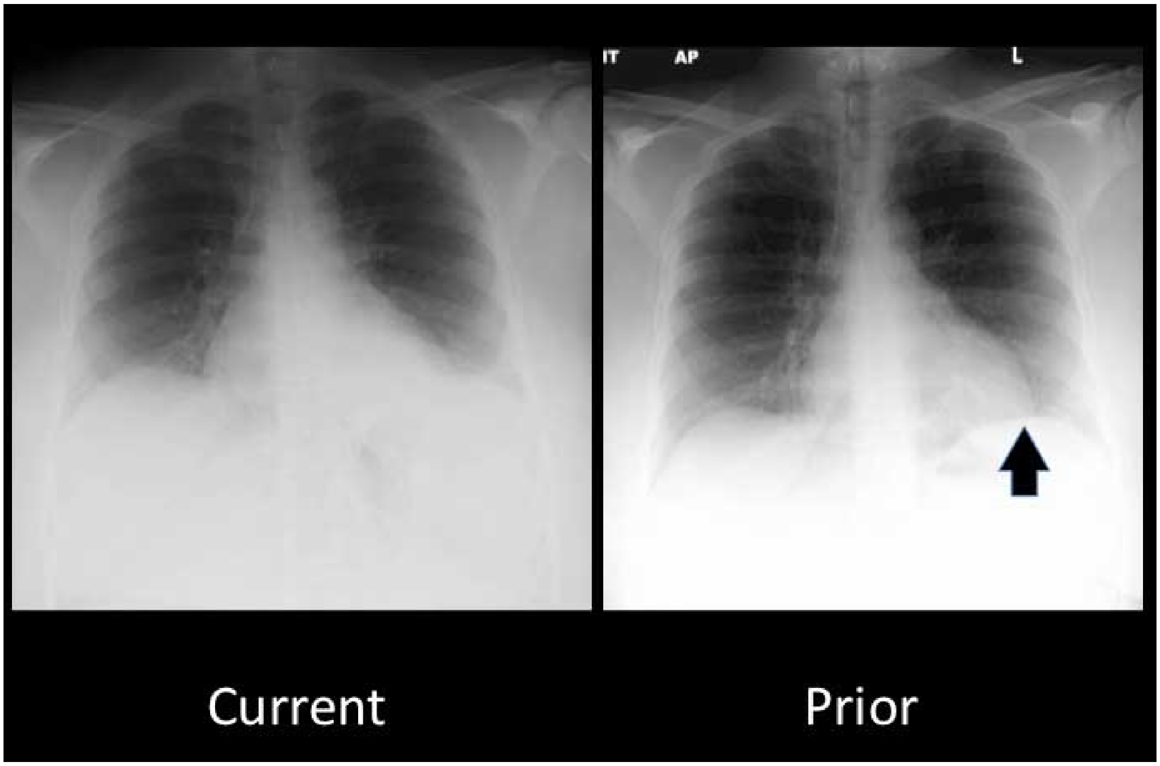

Figure 26

Similarly, on the prior lateral radiograph the thoracic vertebrae become increasingly more lucent as they descend, which is a normal finding (Figure 27, right). Looking at the patient's current lateral x-ray, however, the lower thoracic vertebrae become more opaque (Figure 27, left). This is referred to as the "Spine sign," and is indicative of lower lobe consolidation.

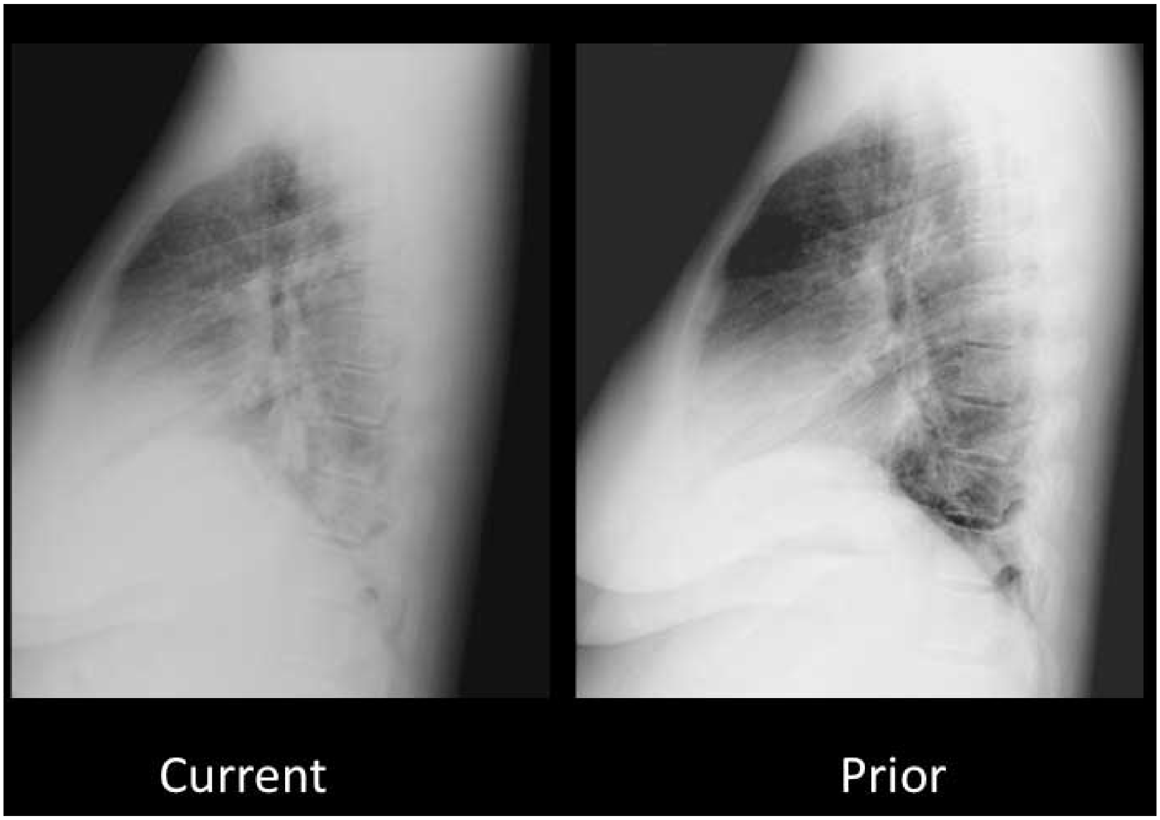

Figure 27

This case underscores several important principles in chest radiology. The first is the importance of checking a lateral chest radiograph. Significant pathology such as effusions, masses, and infiltrates may have only subtle or even absent findings on a PA view alone. Second, as seen in previous cases, one should always compare to prior radiographs, when available. With increasing use of digital radiography this practice is easier than in the past. Third, chest radiographs may grossly underestimate the severity and extent of pathology. It is critical to recognize the significance of subtle findings such as loss of the left hemidiaphragm and the spine sign, and also to recognize when confirmatory studies are required.

Case #7: Shortness of breath

M.D., a 60 year-old female, presented with gradual onset of shortness of breath over the last 2 weeks. It was worse on exertion and with supine positioning. On physical exam she was noted to be mildly tachycardic with a heart rate of 110, blood pressure of 110/56, and a respiratory rate of 24. Her oxygenation was 97% on room air. Her lungs were clear to auscultation bilaterally. The following AP radiograph was obtained and is shown below (Figure 28):

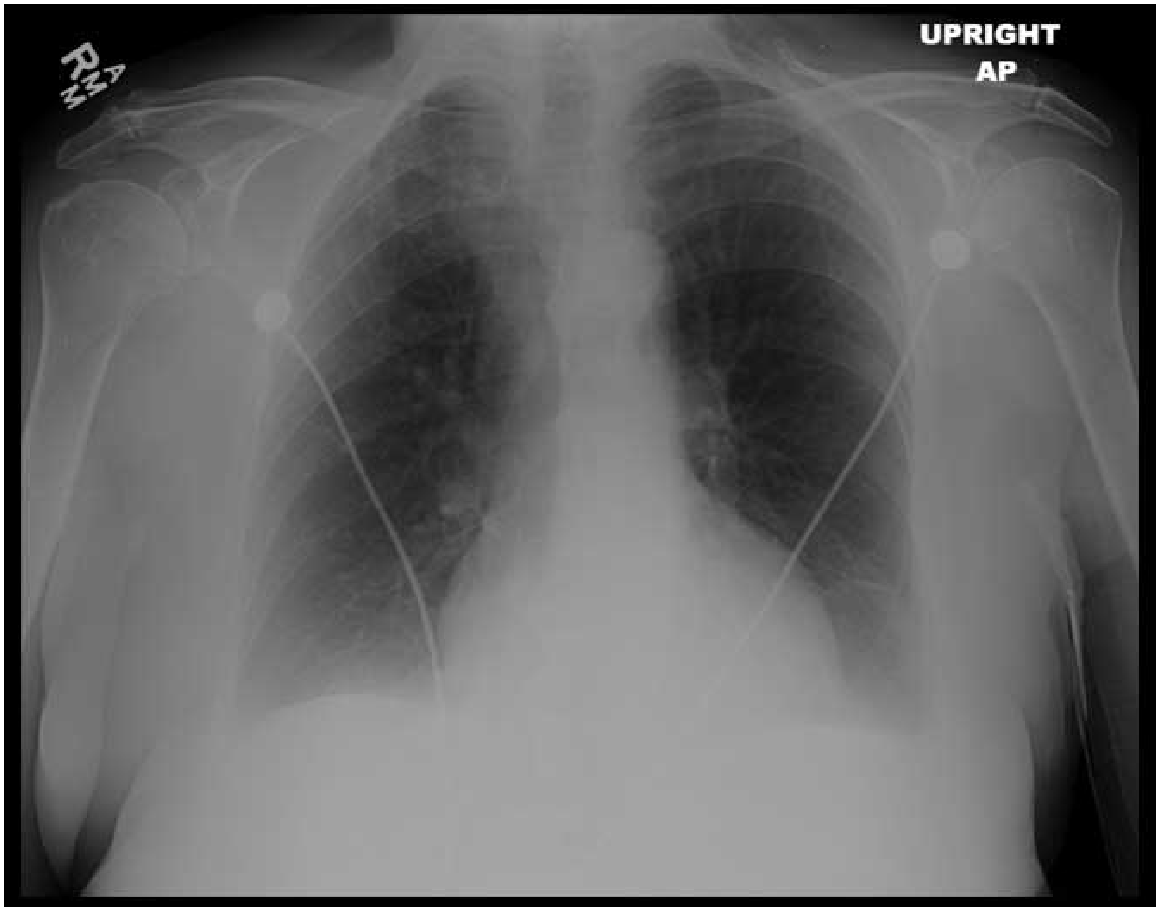

Figure 28

The initial interpretation by the radiologist was cardiomegaly with otherwise clear lungs. Of the note the patient had no prior history of hypertension or cardiac disease. She was admitted to a general medical floor for further workup of her dyspnea. During the night of her admission she became increasingly tachypneic and hypotensive. A stat bedside echocardiogram was performed which confirmed the presence of a large pericardial effusion with tamponade physiology. The patient underwent pericardiocentesis and subsequently was taken to the OR for a pericardial window. Further workup revealed that she had a malignant effusion from previously undiagnosed metastatic breast cancer. In retrospect her chest radiograph from a year prior was reviewed and the cardiomediastinal silhouette was normal (Figure 29).

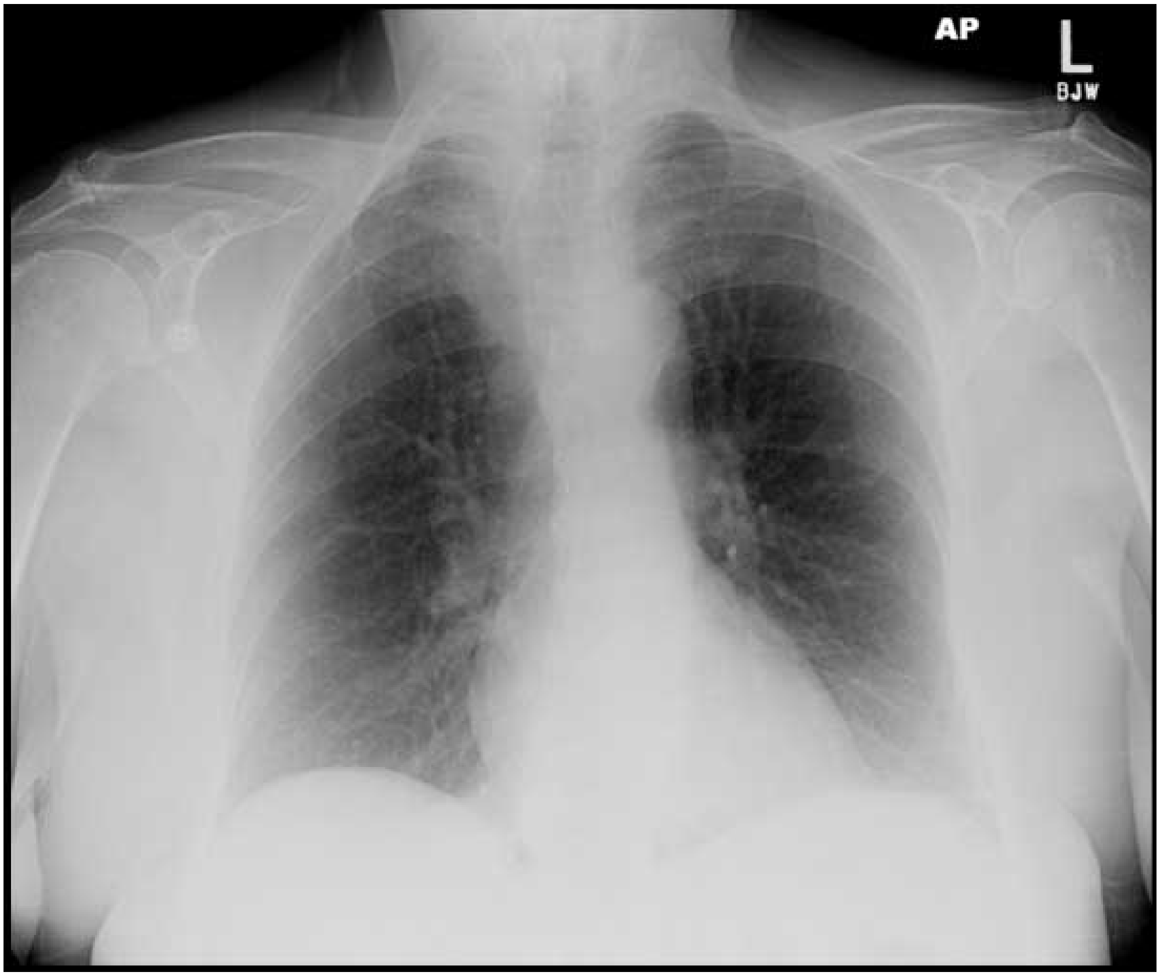

Figure 29

Detection of a pericardial effusion on plain radiographs can be incredibly challenging, particularly with a small effusion. Classically a pericardial effusion may cause a globular or bulbous cardiac contour. However, radiographs may be completely normal in the setting of an acute effusion.

Clinically it should always be suspected in a patient presenting with shortness of breath and clear lungs. It should also be in the differential diagnosis of a patient with cardiomegaly seen on plain radiographs. As in the prior case the practitioner should always endeavor to review prior radiographs if available, as they may yield valuable clues as to the presence of a new effusion. If suspected the test of choice to further evaluate for the presence of an effusion and tamponade physiology is by echocardiogram.[18] The widespread presence of ultrasound machines in the ED and the growing familiarity amongst emergency physicians with performing limited bedside echocardiograms makes this a fast, efficient, and valuable study.

Case #8: Chest pain and shortness of breath

P.S., a 62 year-old female with a past medical history of metastatic breast cancer, presented with sudden onset right-sided, sharp, pleuritic chest pain. On physical exam she was noted to be tachycardic with a heart rate of 130 bpm, tachypneic with a respiratory rate of 22, and an oxygen saturation of 96% on room air. She had no tenderness to palpation of her abdomen. Given her history of active malignancy and her clinical presentation, the woman was suspected of having a pulmonary embolism. Stat PA and lateral chest x-rays were obtained while preparations were made to perform a CTA of the chest. Careful review of the radiograph reveals a very small sliver of free air beneath the right hemidiaphragm (Figures 30 and 31, arrows).

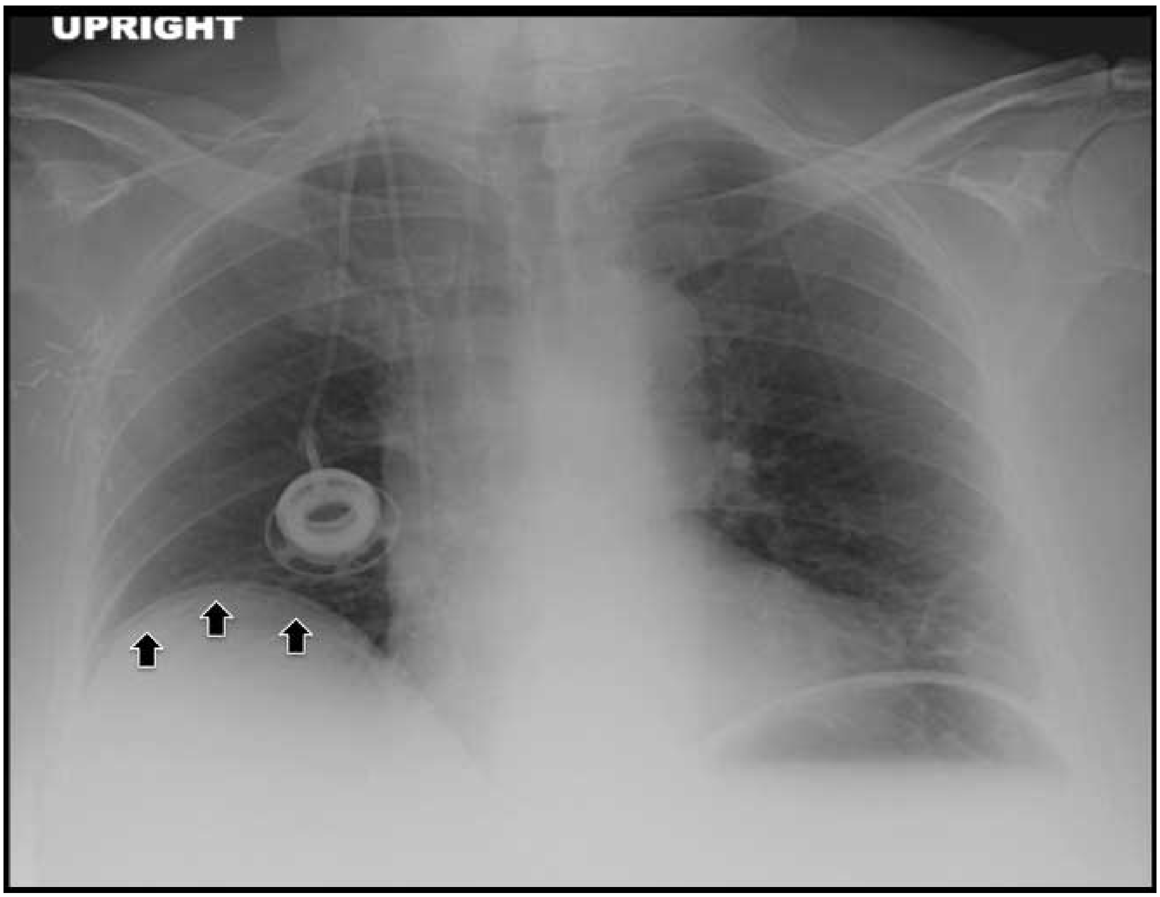

Figure 30

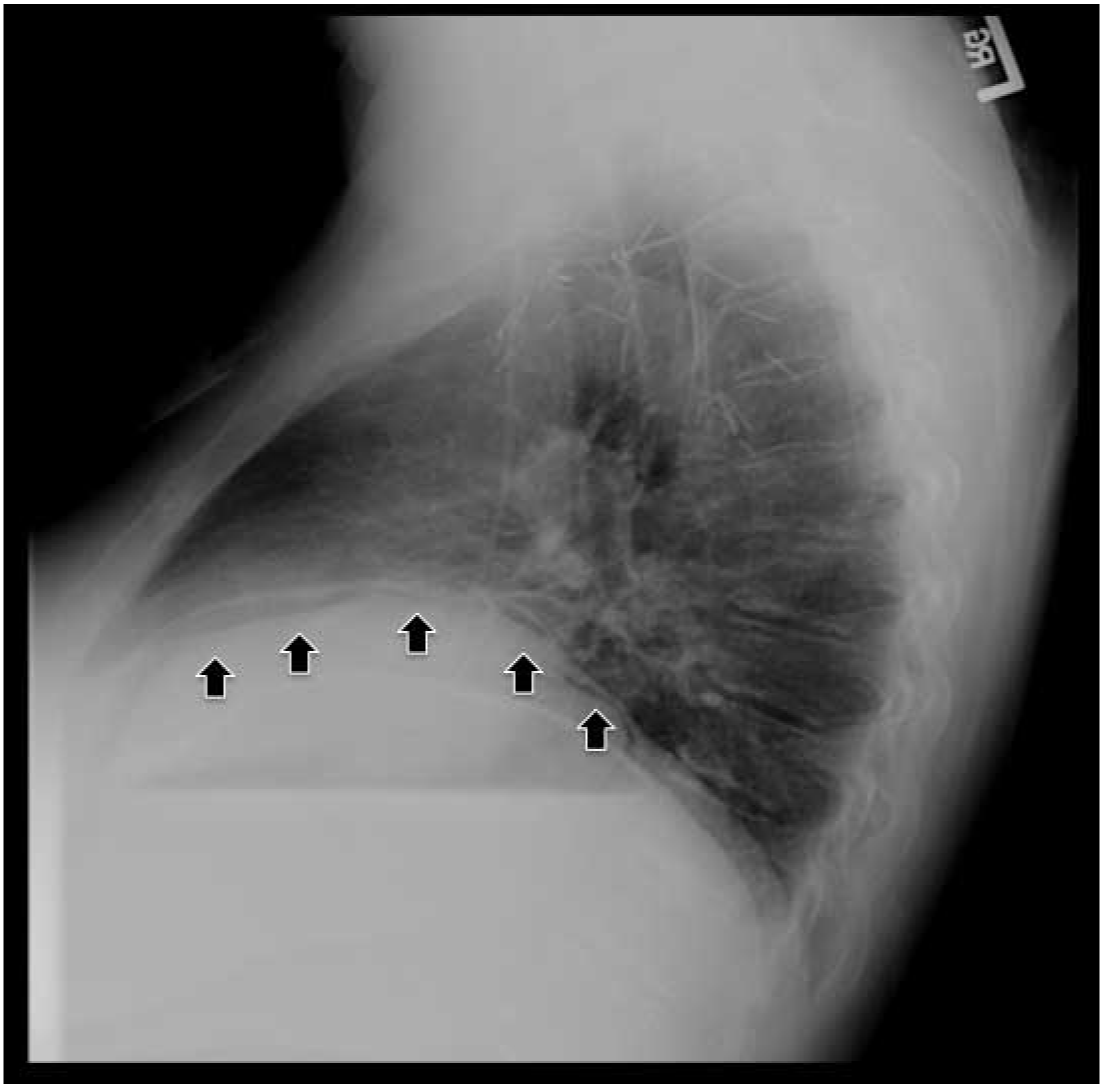

Figure 31

The patient was taken emergently to the operating room for exploratory laparotomy and was discovered to have a perforated peptic ulcer. Upon further review of the patient's medical history she was noted to be on large doses of corticosteroids for her brain metastases, which likely contributed to both the ulcer formation and her lack of abdominal tenderness on exam.

Upright chest x-ray is actually an excellent test for detection of pneumoperitoneum, being able to detect as little as 1-2 mL. However it must be performed correctly.[19] Patients should be upright for at least 5-10 minutes to allow air to collect under the diaphragms. A lateral upright chest x-ray may be even more sensitive than a PA view. It is critical that the emergency physician be systematic in interpreting chest x-rays to detect small amounts of air, particularly when the clinical scenario is misleading as was the case with this patient. It is also important to note that the absence of free air on radiographs does not rule out the presence of a perforated viscus.

Another finding of pneumoperitoneum on plain film includes the "double wall sign," also known as "Rigler's sign."[20] Normally only the air-filled inner wall of the intestines is visible on plain film, as the dense outer wall is compressed against other dense

structures in the abdomen. With the presence of pneumoperitoneum there is both intra- and extra-luminal air, allowing both the inner and outer bowel walls to be visualized. Below is an example in a patient presenting with a perforated peptic ulcer (figure 32, arrows).

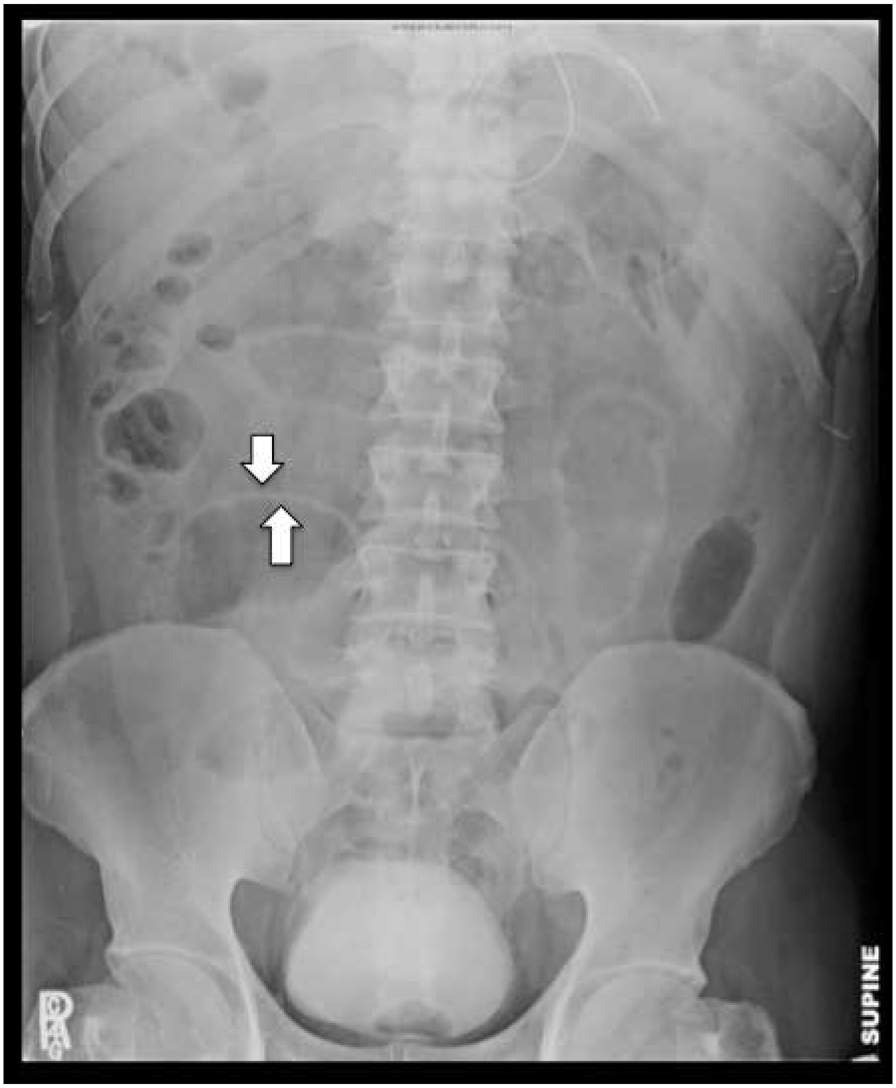

Figure 32

Case #9: Assault

B.D., a 24 year-old female, presented after an assault by her boyfriend. She was struck repeatedly in the head with a blunt object. On her initial presentation she was obtunded with a GCS of 4, and was immediately intubated for airway protection. Her initial vital signs were notable for tachycardia with a heart rate of 110 bpm, and she was saturating 98% on 100% oxygen. The secondary survey was initiated, and was notable only for multiple head lacerations and contusions. During the course of the secondary survey her pulse oximetry continued to trend down. A stat portable AP chest radiograph was performed which is shown below (Figure 33):

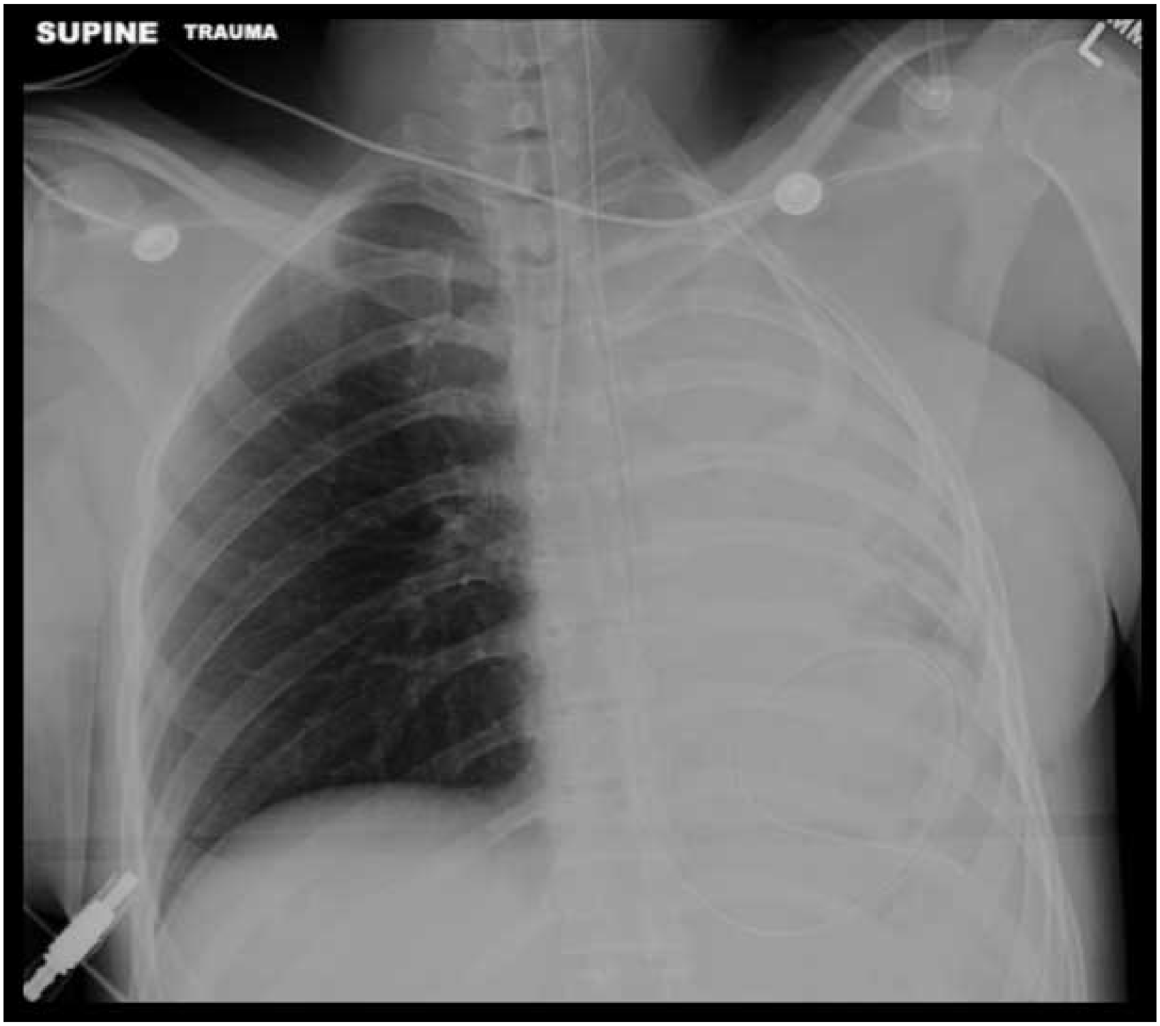

Figure 33

The trauma team evaluated the film and noted the opacification of the left hemithorax. They were particularly concerned by the NG tube which appeared to be curling up into the chest. The team was suspicious for a hemothorax with a concern for diaphragmatic rupture given the position of the NG tube, and the patient was subsequently prepped for the OR. It was only on careful review of the radiograph that it was noted that the endotracheal tube was in the right main bronchus. The tube was pulled back 5 cm, and a repeat x-ray was performed several minutes later (Figure 34). It shows improved aeration of the left lung, and clearly demonstrates the NG tube below the left hemidiaphragm.

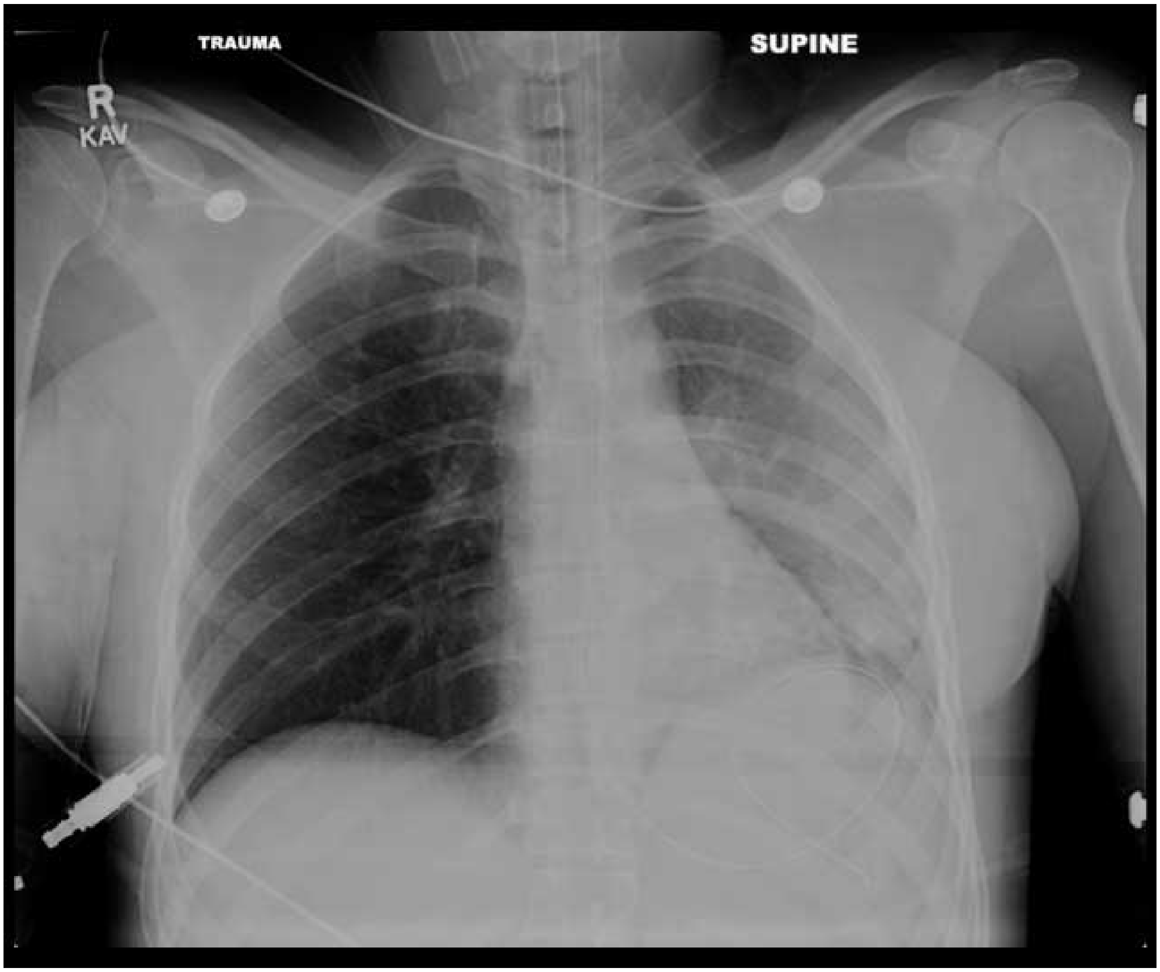

Figure 34

In retrospect, the diagnosis of right mainstem intubation with complete atelectasis of the left lung should have been immediately apparent. It is all too easy to get "happy eyes" when there is an obvious finding, and neglect to evaluate the rest of the radiograph. If a systematic review had been performed initially it would have been obvious that the ET tube was misplaced. In addition, if a diaphragmatic rupture with hemothorax was present, it would have displaced the mediastinum away from the affected side. However, in the initial radiograph the left heart border and the mediastinal structures are shifted *toward*s the affected side. This makes sense when one considers that atelectasis is a retractive process leading to volume loss. In contrast, the radiograph shown below of a patient with a large left pleural effusion clearly demonstrates shift *away* from the affected side (Figure 35).

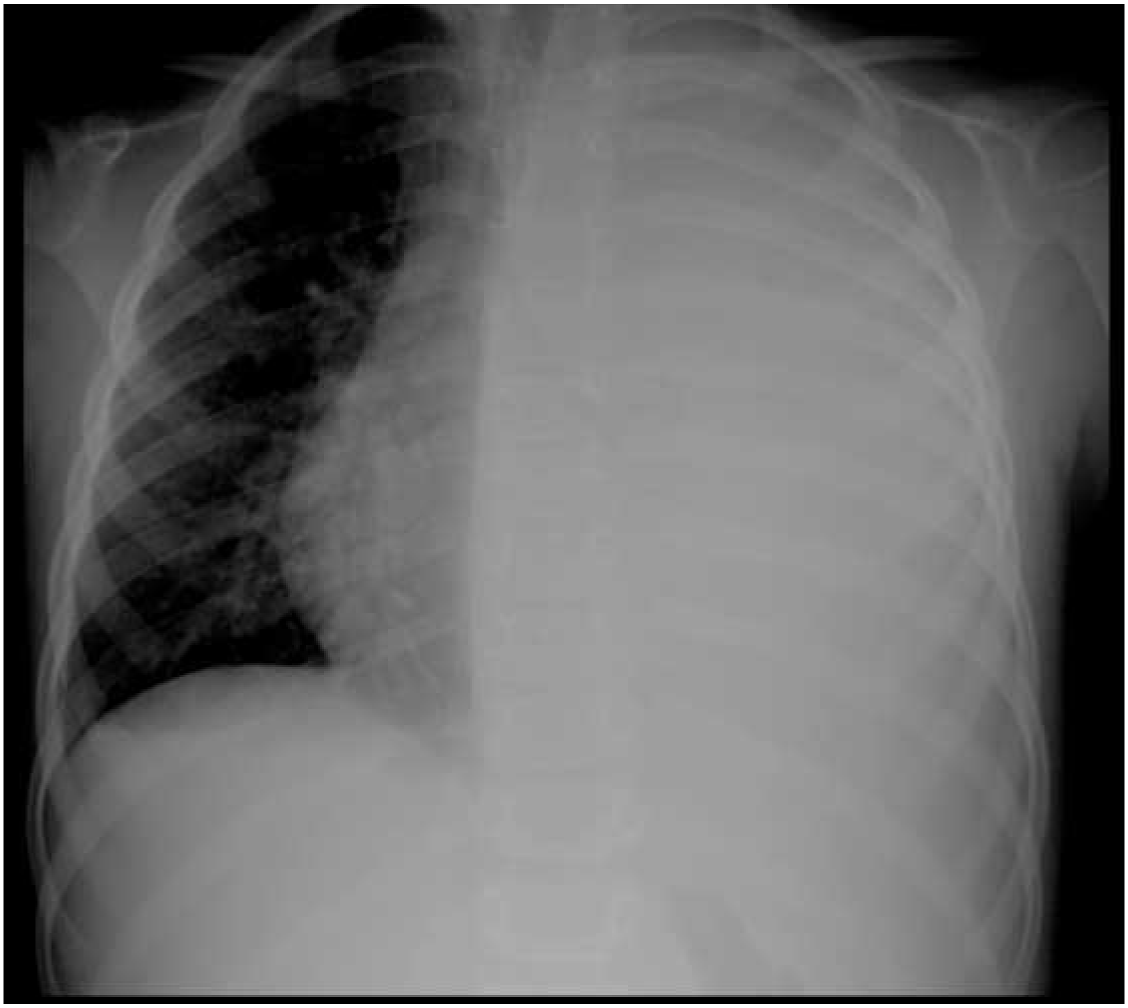

Figure 35

Case #10: Cough

A.V., a 2 year-old female, presented with a 2-day history of low-grade fevers and a cough. On exam she appeared irritable. Her vital signs were notable for a rectal temperature of 99.1° F, heart rate of 144 bpm, respiratory rate of 28, and oxygen saturation of 97% on room air. She had course breath sounds bilaterally, right greater than left. A PA chest radiograph was obtained, and is shown below (Figures 36):

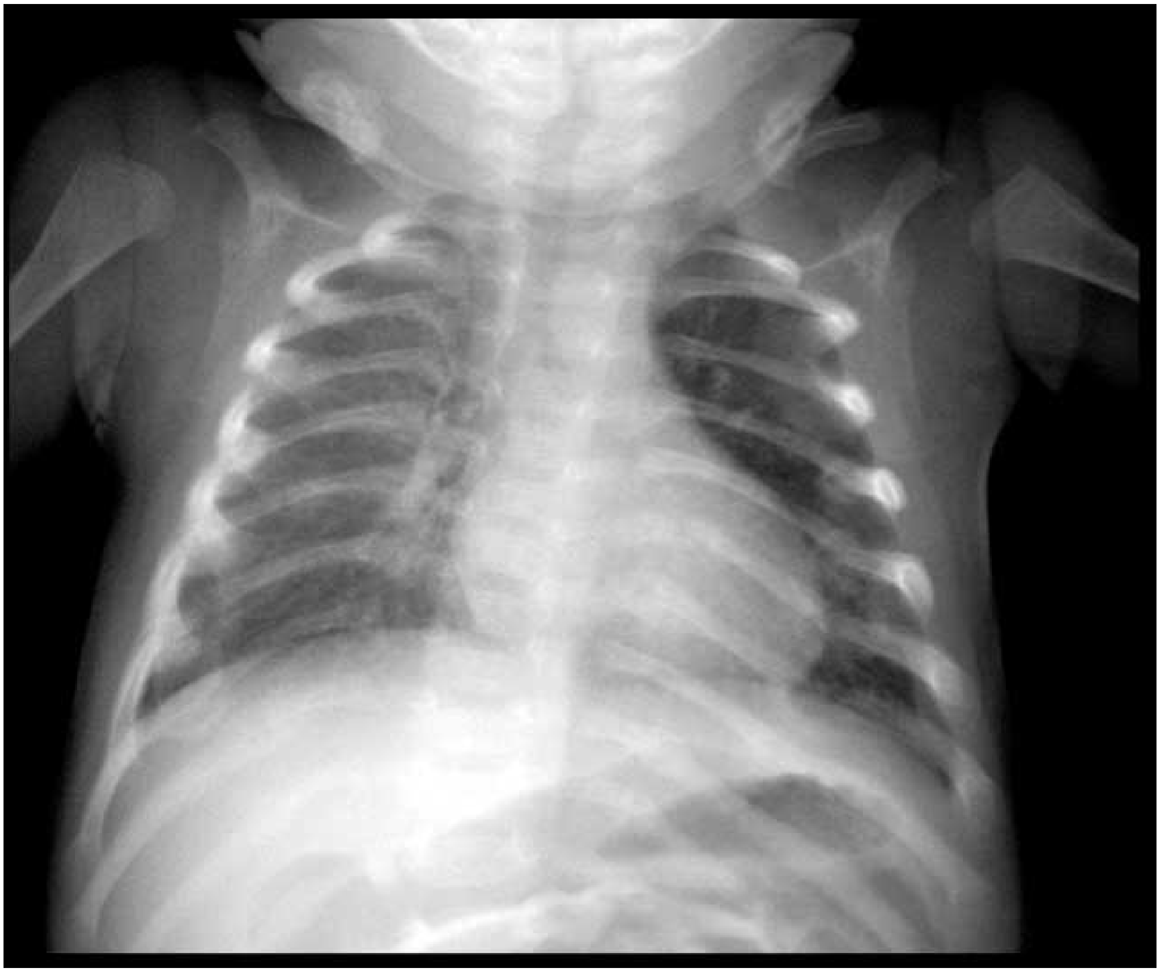

Figure 36

At first glance it appears that there are mildly increased interstitial markings throughout, greater in the right lung fields. On a busy shift with an otherwise well-appearing child one might be tempted to discharge the patient with a diagnosis of viral respiratory infection. However, careful review of the radiographs reveals several other significant abnormalities. There are multiple areas of sudden angulation in the ribs, particularly on the left (Figure 37, arrows). This is consistent with acute rib fractures.

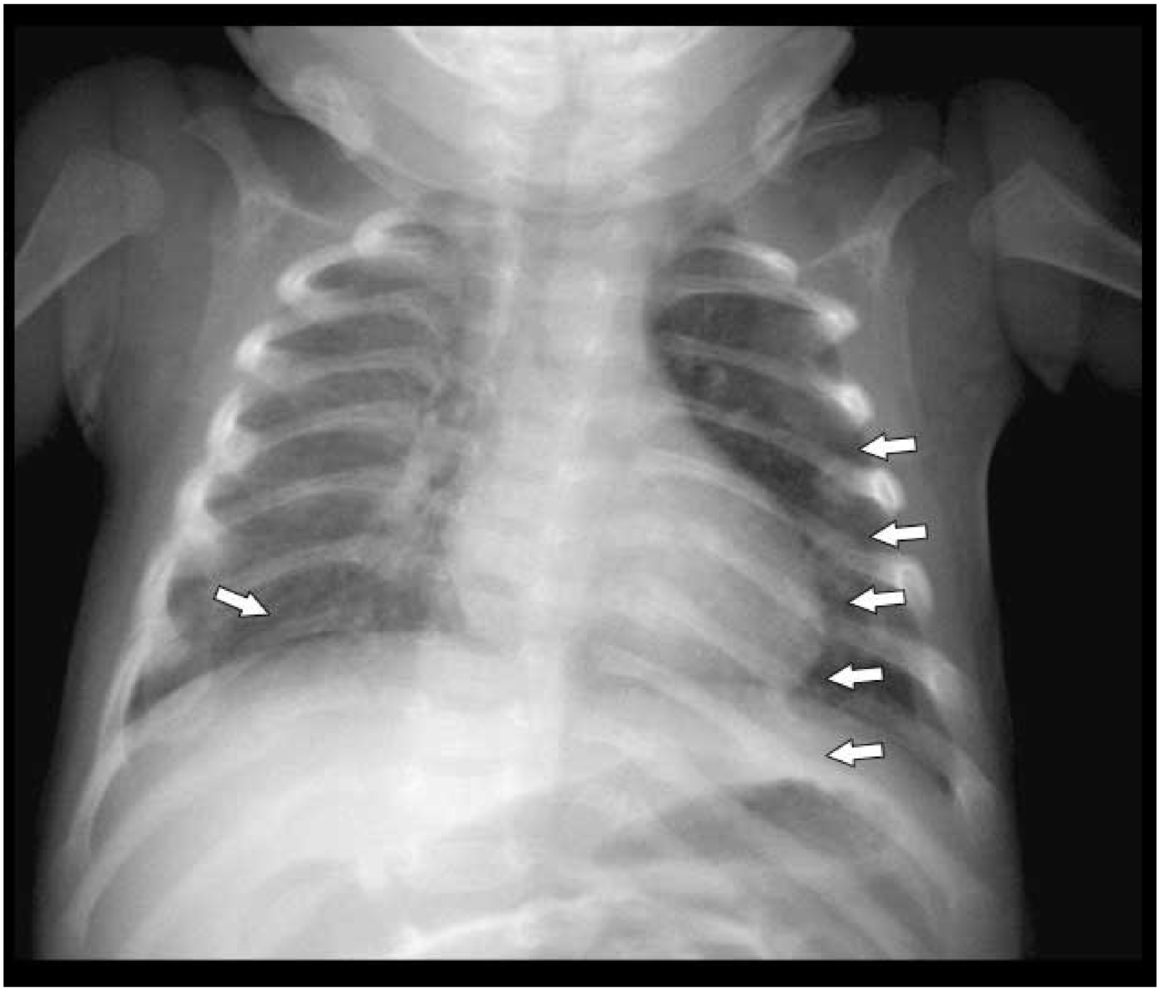

Figure 37

There are also multiple areas of callus formation throughout, indicative of healing rib fractures (Figure 38, arrowheads).

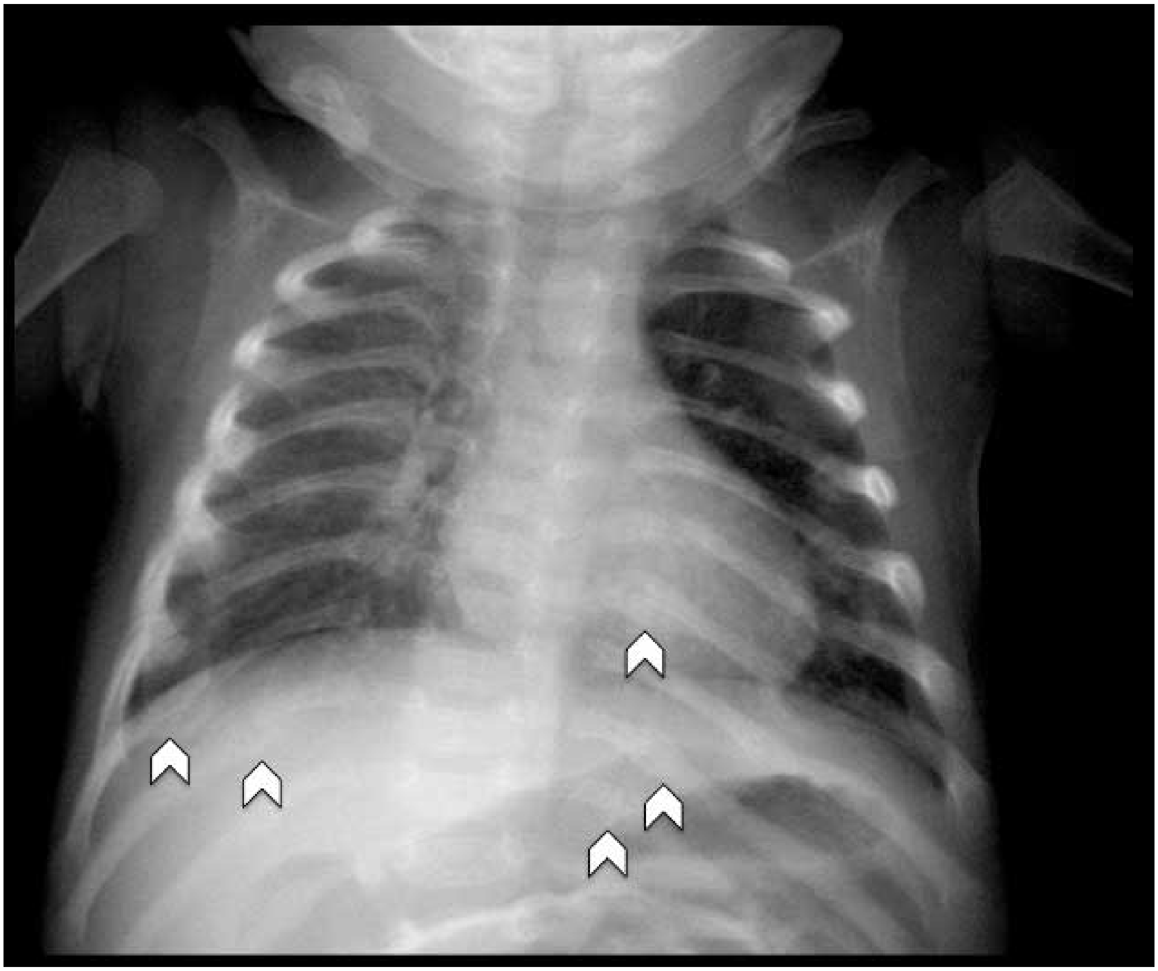

Figure 38

Making the diagnosis of child abuse can be challenging in a busy ED, particularly when the patients are presenting with common, non-specific complaints such as cough, abdominal pain, crying, etc. It is critical that the diagnosis be made in the ED whenever possible, because although the data is conflicting, one study suggests that abused patients discharged home to the same environment have a 50% chance of further abuse, and a 10% chance of death.[21] With estimates of 5 or more children a day dying from abuse,[22,23] this is obviously a serious matter.

The appearance of rib fractures may be very subtle on plain radiographs. One should look for subtle asymmetry of the rib necks, as well as sudden angulation in the ribs as seen in Figure 37. Rib fractures are most visible during callous formation, which typically occurs 10-14 days after injury.[24] It is important to note that in the absence of major trauma, such as from a motor vehicle accident, the probability of abuse in a child with a rib fracture is 71%.[25]

Other radiographic findings of child abuse include periosteal reactions, metaphyseal corner fractures, and bucket handle fractures. Periosteal reaction, or periosteal new bone formation, may be one of the earliest radiographic findings in child abuse, although it may be seen in other disorders as well such as osteomyelitis. It typically occurs in association with a fracture, although it may occur due to subperiosteal hemorrhage without fracture.[26-28] Although the peak incidence is from 10-14 days, it

may appear as early as 4 days from the injury. Figure 39 below shows the typical appearance of periosteal lifting in the distal humerus of a child presenting with arm pain in the setting of abuse.

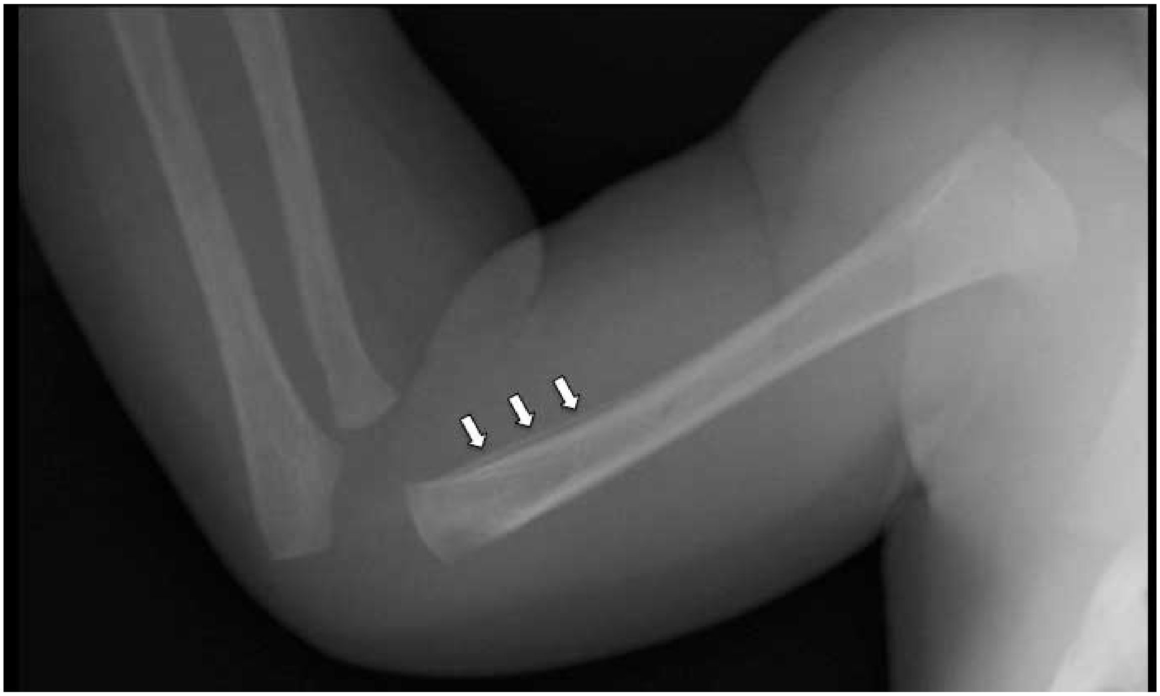

Figure 39

Metaphyseal corner fractures are highly suspicious for abuse, particularly in pre-ambulatory infants.[29] The lesion typically occurs with a twisting force, or when the extremity is forcibly pulled.[30,31] Plain radiographs reveal a disruption in the metaphysis with an underlying lucency. Figure 40 below shows a typical metaphyseal corner fracture (white arrow) as well as periosteal reaction in the proximal tibia of an abused child (yellow arrow).

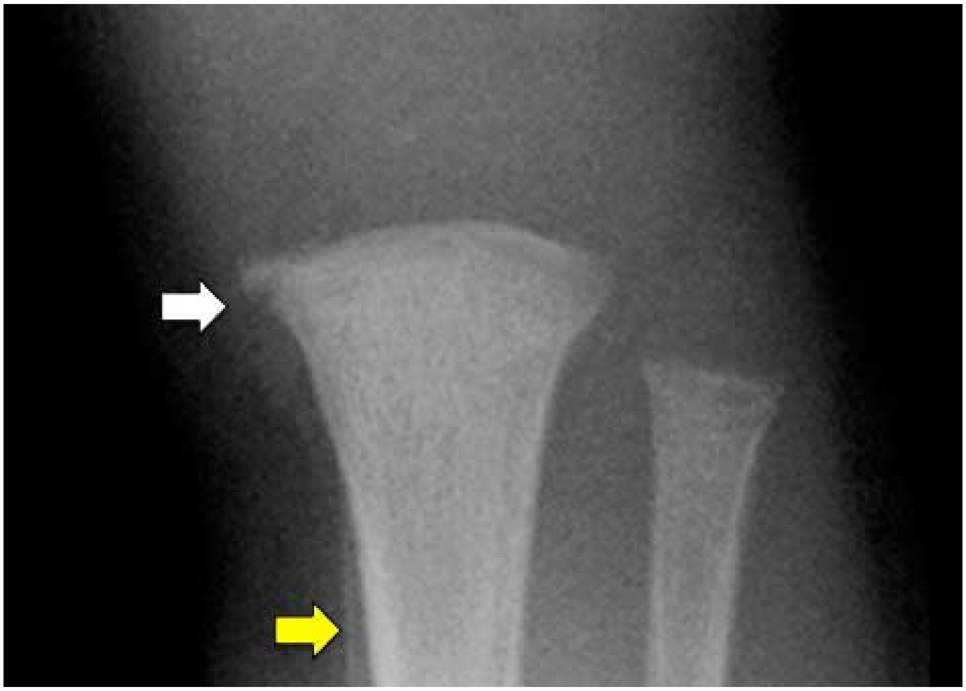

Figure 40

"Bucket handle" fractures are simply metaphyseal corner fractures viewed in an angular projection. The curved density adjacent to the metaphysis resembles the handle of a beach pail. Figure 41 below demonstrates the typical appearance of a bucket handle fracture (white arrow), as well as periosteal reaction of the distal femur (yellow arrow).

Figure 41

Summary

Plain radiographs, particularly chest x-rays, still play a valuable role in the emergency department. They are often the first study to be performed, and subtle findings may lead to the early diagnosis and treatment of potentially life-threatening diseases. Being systematic when reviewing radiographs, reviewing old studies for comparison, obtaining complete studies, and understanding the limitations of plain films are critical skills that the emergency provider must develop to recognize these often subtle findings and to provide the best care for patients.

References:

1. Rao VM, Levin DC, et al. "Trends in Utilization Rates of the Various Imaging Modalities in Emergency Departments: Nationwide Medicare Data from 2000 to 2008." JACR 2011;8(10):706-9.

2. Hagan PG, Nienaber CA, et al. "The International Registry of Acute Aortic Dissection (IRAD): New Insights into an Old Disease." JAMA 2000;283(7):897-903.

3. Von Kodolitsch Y, Nienaber CA, et cal. "Chest Radiography for the Diagnosis of Acute Aortic Syndrome." Am J Med 2004;116:73-77.

4. Klompas M. "Does This Patient Have an Acute Aortic Dissection?" JAMA 2002;287:2262-2272.

5. Luker G, Glazer HS, et al. "Aortic Dissection: Effect of Prospective Chest Radiographic Diagnosis on Delay to Definite Diagnosis." Radiology 1994;193:813-819.

6. Kong A. "The Deep Sulcus Sign." Radiology 2003;228:415-416.

7. Carr JJ, et al. "Plain and Computed Radiography for Detecting Experimentally Induced Pneumothorax in Cadavers: Implications for Detection in Patients." Radiology 1992;183:193-199

8. Lichenstein D, Meziere G, et al. "The 'Lung Point': An Ultrasound Sign Specific to Pneumothorax." Inten Care Med 2000;26(10):1434-40.

9. Rowan KR, Kirkpatrick AW, et al. "Traumatic Pneumothorax Detection with Thoracic US: Correlation with Chest Radiography and CT – Initial Experience." Rad 2002;225(1):210-4.

10. Sartori S, Tombesi P, et al. "Accuracy of Transthoracic Sonography in Detection of Pneumothorax After Songraphically Guided Lung Biopsy: Prospective Comparison with Chest Radiography." AJR 2007;188(7):37-41.

11. Bejvan SM, Godwin JD. "Pneumomediastinum: Old Signs and New Signs." AJR 1996;166:1041-1048.

12. Agarwal PP. "The Ring-Around-the-Artery Sign." Radiology 2006;241;943-944

13. Brody SL, Anderson GV, et al. "Pneumomediastinum as a complication of "crack" smoking." Am J Emerg Med 1988;6:241-243

14. Fajardo LL. "Association of Spontaneous Pneumomediastinum with Substance Abuse." West J Med 1990;152:301-0304.

15. Fadoo F, Ruiz DE, et al. "Helical CT Esophagography for the Evaluation of Suspected Esophageal Perforation or Rupture." AJR 2004;182:1177-1179.

16. Vial CM. "Boerhaave's Syndrome: Diagnosis and Treatment." Surg Clin North Am 2005;85:515-524.

17. Brauer RB, Liebermann-Meffert D, et al. "Boerhaave's Syndrome: Analysis of the Literature and Report of 18 New Cases." Dis Esophagus 1997;10(1):64.

18. Cheitlin MD, et al. "ACC/AHA/ASE 2003 guideline for the clinical application of echocardiography" www.acc.org/qualityandscience/clinical/statements.html

19. Billittier AJ, Abrams BJ, et al. "Radiographic Imaging Modalities for the Patient in the Emergency Department with Abdominal Complaints." Emerg Med Clin North Am 1996;14(4):789.

20. Rigler LG. Spontaneous pneumoperitoneum: a roentgenologic sign found in the supine position. *Radiology* 1941; 37: 604–60.

21. Green M, et al. Ambulatory Pediatrics, WB Saunders, Philadelphia 1968; p285.

22. United States Government Accountability Office, 2011. Child maltreatment: strengthening national data on child fatalities could aid in prevention (GAO-11-599). Retrieved from http://www.gao.gov/new.items/d11599.pdf

23. U.S. Department of Health and Human Services, Administration for Children and Families, Administration on Children, Youth and Families, Children's Bureau. (2011). *Child Maltreatment 2010*. Available from http://www.acf.hhs.gov/programs/cb/stats_research/index.htm#can

24. Albert MJ, Drvaric DM. "Injuries Resulting From Pathologic Forces: Child Abuse." In: Pediatric Fractures: A Practical Approach to Assessment and Treatment, Williams and Wilkins, Baltimore 1993; p. 388.

25. Kemp AM, Dunstan F, et al. "Patterns of Skeletal Fractures in Child Abuse: Systematic Review." BMJ 2008;337:a1518.

26. Chapman S. "Radiological aspects of non-accidental injury." J R Soc Med 1990;83(2):67-71.

27. Worlock P, Stower M, et al. "Patterns of Fractures in Accidental and Non-accidental Injury in Children: A Comparative Study." Br Med J. 1986;293(6539):100-102.

28. Carty HM. “Fractures Caused by Child Abuse.” J bone Joint Surg Br 1993;75(6):849-857.

29. Arkader A, Freidman JE, et al. “Complete Distal Femoral Metaphyseal Fractures: A Harbinger of Child Abuse Before Walking Age.” J Pediatr Orthop 2007;27(7):751-3.

30. Lazoritz S, Baldwin S, et al. “The Whiplash Shaken Infant Syndrome: has Caffey’s Syndrome changed or Have We Changed His Syndrome?” Child Abuse Negl. 1997;21(10):1009-14.

31. Caffey J. “The Whiplash Shaken Infant Syndrome: Manual Shaking by the Extremities with Whiplash-Induced Intracranial and Intraocular Bleedings, Linked with Residual Permanent Brain Damage and Mental Retardation.” Pediatrics 1974;54(4):396-403.