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**SYSTEMATIC APPROACH TO REQUESTING AND INTERPRETING CHEST X-RAY
AND ITS PRINCIPLES: WHAT EVERY CLINICIAN MUST KNOW**

SYSTEMATIC APPROACH TO REQUESTING AND INTERPRETING CHEST X-RAY AND ITS PRINCIPLES: WHAT EVERY CLINICIAN MUST KNOW

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ABSTRACT

Introduction: Clinicians should be able to exclude major abnormality in radiographs, while the radiologist is abased with high complex imaging. In both medical and surgical practice, X-ray is the most common imaging for diagnostic and therapeutic uses. For initial assessment, plain X-ray is the finest method to visualize the bony skeleton. Chest X-ray (CXR) is the main modality to visualize the lung, pleura and mediastinal abnormalities. Clinicians making chest X-ray request must be mindful of dangers of radiation exposure. The number of chest radiographs requested can overwhelm the number of radiologists in developing countries. Quality assurance studies show discordance between interpretation reports by emergency physicians and radiologists narrowed to 1.1% from 45% in developed nations. Basic chest X-ray is what every doctor that contact patients must be competent at interpreting starting with medical students, to close the discordance gap in developing nations, and hence the purpose of this paper which presents the principles guiding chest X-rays, from request to interpretation as a refresher that improves clinician's diagnostic accuracy.

Methods: Relevant literature search using key words like chest, X-ray, systematic, interpretation and clinician in Medline, Ajol, Embase and Google scholar were done. Articles were selected for relevance to chest radiograph.

Results: A detailed guide to requesting and interpreting CXR is presented

Conclusion: Clinicians can increase precision of chest X-ray interpretation acumen from practice and training.

Keywords: Chest, X-ray, Clinician, Interpretation, Principles, Request, systematic

INTRODUCTION

Clinicians should be able to exclude major abnormality in radiographs, while the radiologist is abased with high complex imaging.^{1,2} In both medical and surgical practice, X-ray is the most common imaging for diagnostic and therapeutic uses.² For initial assessment, plain X-ray is the finest method to visualize the bony skeleton.^{2,3} Chest X-ray is the main modality to visualize the lungs, pleura and mediastinal abnormalities.⁴⁻⁷ Clinicians making chest X-ray request must be mindful of dangers of radiation exposure. The number of chest radiographs requested can overwhelm the number of radiologist in developing countries.⁶ Quality assurance studies shows discordance between interpretation reports by emergency physicians and radiologists narrowed to 1.1% from 45% in developed nations.⁸ Basic chest X-ray is what every doctor that contact patients must be competent at interpreting starting with medical students, to close the discordance gap in developing nations,^{6, 9} and hence the purpose of this paper.

X-rays, a serendipitous discovery in 1886 by Conrad Wilhelm Roentgen has revolutionized the world of imaging for health and when

naming his invention, he proffered the term 'X-ray' rather than his name.^{2,5}

Single frame radiograph, radiotherapy, intervention fluoroscopy and computed tomography use X-rays and are indispensable in treatment and diagnosis of patients with an estimated 2500 million diagnostic radiologic exams, 5.5 million radiotherapy sessions and 32 million nuclear medicine examination performed worldwide.¹⁰ The number of chest radiographs requested can overwhelm the number of radiologist in developing countries like Ghana and Nigeria, for a thorough assessment considering that they also use other imaging modalities such as computed tomography, magnetic resonance imaging among others.⁶

X-rays for clinical uses help in diagnosis and treatment of patients and enhance the monitoring of patient prognosis in conditions that warrants serial radiography such as its use in fractures, pleural and pericardial effusion, intestinal obstruction and foreign body impaction.² Chest X-ray is seen as a first line imaging in the placement and positioning medical device such as endotracheal tube, chest tube insertion, central vein catheter to mention a few.^{4,7} It is the commonest radiological test done and regularly requested in emergency department, trauma units, routine medical checkups and pre-operative assessment for patients going for surgery.⁷ Emergency physicians and paediatricians order a lot of imaging to make decision on patient management and such images are later reviewed by attending radiologist for quality assurance with studies revealing discordance between the reports as high as 45% in the past, with a marked reduction rate of discrepancy to 1.1% now.⁸ Radiological signs are a group distinctive of abnormality that are characteristic of a disease or a group of pathology.

Basic chest X-ray is what every doctor must be competent at systematically interpreting. The Royal College of Radiologist (RCR) stressed among other imagings, that medical students should be conversant with chest X-rays normal structure and pathologic interpretation of common condition of pleural

effusion, pneumothorax, lung consolidation, pneumoperitonium and heart failures.⁹ Other investigators reports the inability of house officers and junior doctors to make basic radiological diagnosis.⁶

Mechanism of action of X-ray radiation

Cathode ray tube was the technology that gave birth to X-ray when its electron beam was focused to strike an added target (an anticathode) that made Wilhelm Conrad Roentgen notice the fluorescent screen (a plate covered with barium platinocyanide) glowed and uses ionizing radiation across tissues.^{2,10} The earth has abundant ionizing radiation which exposes living things to some of its dangers and merits, however 2% of total ionizing radiation impacted to human beings come from medical exposure but vast natural radiation account for 85% of exposures to human.¹⁰ These comes from cosmic rays, radon rays and excessive ultraviolet rays.^{1,2}

On exposure to ionizing radiation, ions are created in tissues when high energy delivered removes electrons in the orbit by stretching their binding force.^{2,11} The ionizing radiation causes damage to D.N.A directly and a second method of damage occurs indirectly from production of toxic free radicals that breaks down D.N.A strands.^{2,11,12} Damage effect to D.N.A can be either to the single strand which is milder, repaired quickly but occasionally mis-repair is associated with induction of cancers or double strand DNA damage that are not easily repaired.¹¹

Ionizing radiation leading to D.N.A damages as explained above exerts its effect either through non-stochastic effect that is non dose dependent, but risk increase with exposure or the stochastic effect that is dose dependent seen in chronic exposure such as in fluoroscopy or nuclear medicine.^{1,2}

Principle of X-rays in general

X-ray films are taken using an X-ray machine enclosed in an X-ray room which has a fortified wall imbedded with lead to prevent hazard to environment. Radiographers use various shields like the lead apron and some precautionary use of dosimeter to monitor

exposure. It is difficult to prevent unwanted X-ray beam from radiation exposure to patients in those clinicians that come close, like the intervention pain physicians that use fluoroscopic X-ray beam and orthopaedic surgery procedures that increase risk of occupational exposure to staffs and patients.^{11,13} Proper shielding of such radiation beam is the most important factor towards reduction and other factors are time of exposure and distance from source while lead apron and thyroid shield forms standard shields for safety of medical staffs involved in interventions, with others being lead glasses, table-side or patient lead drape, radio-protective caps and gloves.¹³

X-ray can be taken in various positions such as erect, supine, and decubitus position. They are absorbed differently by body tissues which reflects the appearance on captured images and is dependent on the tissue or organ density.

The principles entails that more dense tissue or organ hinder the transmission of X-rays through the body to the film and will appear white or whiter, while less dense tissue or organ will allow X-rays to pass readily through the body to the film and will appear darker. Hence, the lung field appear darker while the bony ribs appear whiter. The human body radiologic densities in ascending order are; *air, fat, fluid, bone and metal*.^{1,2,14}

- The X-ray AP view has the film placed at back of the patient while the X-ray is emitted from front. It can be handy for very sick patients but has a poorer appearance. A mnemonic to remember is **FAP** –Film At Posterior (for AP radiograph)
- The PA view has the radiology film placed in front of the patient while the X-ray emitted from behind relying on the patient's ability to sit or stand thereby giving a better outlook. A mnemonic to remember is **PAF** –Place Anterior Film (for PA radiograph)

The principle of position is that the closer the organ is to the radiological film the sharper the boundaries and the size of the organ translating that, for AP film that is

farther to anteriorly placed organs like the heart will appear to have hazy boundaries and larger in size while the PA film that is closer to the anterior placed organ like the heart gives a sharper boundary and appropriate size. Other chest X-ray views include the lateral, lordotic, and decubitus. The lateral view should be labelled right (RT) lateral or Left (Lt) lateral to designate the side that is of interest for evaluating the patient's disease and placed close to the X-ray detector.¹⁵ Its indication includes determining relations of structures in the AP location as well as hilar, mediastinum, costal ribs, costophrenic recess and diaphragm.¹⁵ Apical view gives more information about the lung apices to visualize areas that are hidden by clavicles, first rib and costochondral junction by patients upper posterior back leaning about 30° to the detector while when the patients lower anterior chest leans on the X-ray detector, it takes the lordotic view which is for lower lung lobes, left lingular and right middle lobe.¹⁵ The lateral decubitus is for detecting free pleural fluid and pneumothorax while the oblique view add information to lateral lesions that may be proximal to the chest wall.

Principle of risk, exposure and prevention of X-ray irradiation

Exposure source to ionizing radiation are of three (3) types: (1) the primary beam giving the direct exposure,² (2) Leakage from X-ray tube and (3) scattered radiation reflected from patients body and table.¹⁴ Main exposure to health personnel and orthopaedic surgeons is from scattered radiation rather than the primary beam.¹⁰ As stated by Lakhwani et al¹⁰ the triad of exposure risk are "Time-Distance-Shielding"; Lead apron of 0.5mm thickness approximately shield 99% of potential radiation dose.

10 - 20 mrad is the skin exposure doses and 1mrad gonadal exposure of a standard chest X-ray.¹⁰ A thermoluminescent dosimeter (TLD) badge is worn by radiology staffs and is regularly measured for radiation dose.¹⁵

To ensure radiation safety, measures such as the use of lead apron and wraparound double lead apron for pregnant women are utilized. Other important ways are to curtail unnecessary repeat films and staffs should be in a protected room during X-ray exposure.¹⁵

Principles of chest X-ray request

- ✓ Proper filling of chest X-ray request form – Biodata that includes patients name, age, sex, hospital number, contact address and important clinical symptoms and signs with their duration of onset is required. Studies have reported a correlation that is directly proportional between a radiologist interpretation of X-ray reading and the information provided to him.^{2,3} To buttress the value of clinical note in making a request, Hook¹⁶ stated

“ Two or three pairs of eyes are always better than one, and remember that you have the advantage of the patient who the radiologist seldom sees face to face, so be sure to provide that third side of the diagnostic triangle-history”.

- ✓ Choice of view and rules- adhere to the rules of two's when requesting a chest X-ray at the least:²
 - Two (2) views –AP & lateral or PA & lateral – at least two

views not limited to AP and PA (figures 1A & 1B) but can be AP & oblique or PA & oblique as well

- Two (2) different times – can be pre procedural or post procedural, similarly is comparing an old film with a new film at different times taken

The clinical implication of the rule of twos in figure 1 is that in the AP view (Fig.1A), the arrow head entry point may be uncertain and the haemothorax from injury can be underestimated (say 500mls) while a cardiothoracic surgeon may be inclined to plan for an anterior lateral thoracotomy approach. Looking at the lateral view (Fig.1B), the haemothorax appears more probably about twice or thrice the volume, and a posterior lateral thoracotomy approach may take precedence with more certainty. The meniscus sign or Ellis curve is a radiological sign of pleural fluid collection and Damoiseau-Ellis line is when it is clinically demonstrated as the summit of percussion dullness over the pleural collection in the hemithorax. Note that the scapula is rotated out of the lung field in PA view (Fig 1A) but part of it may obscure the lung field in AP view which is an important distinction too.



Figs 1 A & B: Chest x-rays with penetrating metal arrow chest injury and meniscus sign from haemothorax.
Note that the bamboo/cane shaft or stalk of the arrow was removed

Principles of chest X-ray interpretations

1. Remember positioning – accurate placement of X-ray on viewing box is a prerequisite for effective interpretation. Place the film with the label (right side or left side) clinically scrutinized as labelling errors do occur (Figure 2- the 'L' is written in mirror image). Re-check the patient's identification of name, hospital number and date taken so that you don't interpret a wrong film or a very past one. Clinicians must be conversant with the changing trend in technology as a number of teaching hospitals in Nigeria and Africa are deploying the e-health system with radiologic request and films viewed rather on personal computers (PC), a dawn of teleradiology. Whether the viewer or viewing box will remain relevant or become an archive will be the judgment of time.
Symmetry of the chest X-ray position should have the sternocleidomastoid joint at equidistant to the midline thereby avoiding tilting. Another landmark is that the clavicle heads should be equidistant to the spinous process in the midline. The spinous process is aligned to an imaginary mid vertebral line that is at the middle way between the left and right clavicular heads (figure 4 - shows unequidistant clavicular heads).⁷
2. Check for motion by noting sharpness of the diaphragmatic contours, pulmonary vasculature and the upper cortices of ribs.⁷
3. Remember the dictum "dark for air and white for bones" in the film presented.² Four (4) densities exist in radiographs from black ascending-gas, fat, water, and mineral (bone), to white.¹⁶
4. Artifacts can result in misdiagnosis and should be ruled out when in doubt. When in doubt that can jeopardies clinical decision intervention on a patient, don't hesitate to repeat the radiograph.

5. Develop, train and master a systematic approach to reading the chest X-ray. It can either be from outward to inward – skin, subcutaneous tissue, ribs and intercostal muscles, lung field and the mediastinum containing the heart, great vessels and the oesophagus or from inward to outwards. No dogma exist and whichever method chosen is at the discretion of the clinician but the catch is to stick to one method and master it. For this discourse, the PA view will be used, and I prefer to go from outwards to inwards as I find it a logical sequence as sometimes the clinician come into contact with the film while seeing the patient during ward rounds or at the clinic.

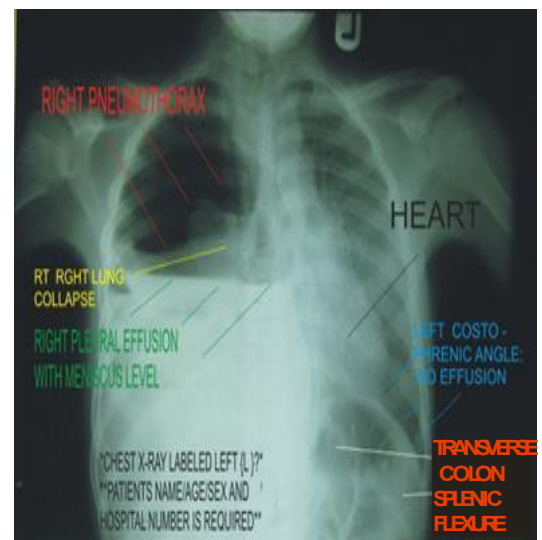


Figure 2: Chest X-ray PA view of a 14-year-old, with right pneumohydrothorax

Steps in Chest X-ray interpretation after placement on the viewing box (or on PC)

- a. Check adequacy of chest X-ray
 - Inspiration chest X-ray with the diaphragm below 8 -10 ribs posteriorly and 5 or 6 rib anteriorly.^{2,7,17} Better inspirational film is seen in PA. Shallow supine breath limits AP.
 - Expiration film at deep expiration, the diaphragm can reach the level of the nipple and is at risk of injury together with

- abdominal viscera in penetrating chest trauma.
- Positioning – Head of clavicles should be equidistance to the spinous process as discussed above and bony detail of vertebral spine are not visualized but the disc spaces are visualized for well taken adequate film.^{2,17}
- b. Skin and subcutaneous tissue – the subcutaneous tissue is checked for asymmetry between the contralateral sides. Subcutaneous emphysema can denote pleural leak or trachea - bronchial injury that will appear as dark radiolucent shadows while haematoma will appear radiopaque. Significant subcutaneous emphysema should be assessed either clinically or radiologically (or by both), so check for Ginkgo leaf sign of radiolucent air striation in the soft tissue over the pectoralis major muscle fibres on CXR. It can result from from subcutaneous side-port migration, chest tube blockage or initial inappropriate chest tube insertion.¹⁸ A clinician who notices progression of emphysematous shadow should promptly inspect the tube and when it coincides with inadequate or no drainage, the tube will need replacement, repositioning or removal of clog in the chest tube causing blockage, otherwise it may result in tension pneumothorax.¹⁸
- c. Bony ribs – check for symmetry of the rib as you make a quick first glimpse from above downward. Go back for a second proper reading to outline the ribs for any pathology. Fracture of the ribs will show discontinuity of the bone and fracture line. Fracture of the first and second ribs is indicative of severe trauma and multiple fractures can occur. An important aspect of the bony skeleton of the chest is its vital role in respiration that impacts on overall tissue perfusion, hence multiple rib fracture should be sorted out.

A flail chest is when there is fracture of two or more segment of a rib or two or more consecutive fractured ribs and/or sternum with paradoxical motion as the segment is not fixed during inspiration and expiration.^{2,18,21} Flail has two components-the orthopaedic which involves the ribs, and pulmonary which involves the lung as during respiration, inspiration is marked by inward movement of the flail segment and vice versa calling for strapping by clinician to curtail pain and ventilation-perfusion mismatch.^{18,21}

- d. Check for the position of the diaphragm. The right diaphragm is placed at a higher level than the left owing to the presence of the liver which gives it some protection in trauma as studies suggest the incidence of left diaphragmatic injuries in trauma is 85% - 90% when compared to the right. Unilateral elevation can occur in phrenic nerve injury or ipsilateral atelectasis.
- e. Pleural space – the pleural space may account for conditions that can accumulate air or fluids in the form of pneumothorax, pneumohaemothorax, haemothorax, pyothorax and chylothorax. Early or late complications can be detected by requesting a chest X-ray before clinical sign appears such as prevention of tension pneumothorax through early capture of small pneumothorax.⁴ Procedures such as chest tube insertion will require a pre and post insertion X-ray with the latter requiring serial check X-ray even after extubation.
 - Pneumothorax will show radiolucency and absent lung markings (Figure 2)
 - Small pneumothorax will show 'thin white line' A visceral white line is seen when separation of the parietal and visceral pleura occurs due to air resulting in white line of visceral pleural in

plain chest radiograph but must be differentiated from a skin fold which when traced extends outside of the lung.²⁰ Deep sulcus sign is the presence of air in the costophrenic angle appearing as dark radiolucent when compared with the opposite costophrenic angle in a supine chest X-ray due to accumulation of air in the anterior and basal nondependent part of the pleura.²⁰ The figure 2 below shows an erect Chest X-ray with air collecting at the apical or upper half of right hemithorax in a case of pneumohydrothorax.

- Pleural effusion is accumulation of fluids in the pleural space. It occupies the lower right hemithorax in figure 2 below for a case of pneumohydrothorax. Isolated haemothorax can occur with blood in the pleural space as seen in trauma (Fig 1A&B) or catamenial pneumothorax/catamenial haemothorax- which occur during early menstrual cycle in young women. When there is obliteration of the costophrenic space with fluid such as blood, it can signify about 200 – 300 milliliters by estimation.

- f. Lung field- normal lung field appears with orientation of the vasculature of lower lungs being larger than the upper but the reverse occurs with increase pulmonary venous drainage in heart failure from circulation overload – cephalization.^{2,17} Kelly B lines that are horizontally placed and less than 2cm found at the lung bases are seen in pulmonary oedema.^{2,21} A pathology of the lung could be obscured by other chest wall tissues and disease as this re-echoes the saying of accuracy of radiographic interpretation is directly related to history provided. Figure 3 below is a

chest X-ray of a patient having advanced fungating breast cancer with metastasis to the lungs showing cannon ball lesions in the left lung field and fluid in the hemithorax (from malignant pleural effusion); both obscured by the tumour over the chest from the breast tissue. Osteoblastic or osteolytic metastasis in ribs, sternum and thoracic vertebra should be routinely checked in all chest X-ray reviews.

Lung collapse (atelectasis) - Fluid or soft tissue replacing air in the distal airway causes consolidation and TB is a common cause of collapse consolidation showing radiographic opacities and volume loss.¹⁵ Indirect signs are ipsilateral displacement of structures to the collapsed side such as hilar/ mediastinum shift, diaphragmatic elevation, and contralateral compensatory emphysema. Direct signs include crowding of vessels, shift of fissures and increased opacities.¹⁵

Look for hilar lymphadenopathy which is most common in children with Tuberculosis (TB). TB screening is worth mentioning as symptomatology, purified peptide derivative (ppd) and chest X-ray are the three conventional screening tests with the latter having a higher sensitivity of 86% and specificity of 89%. Physicians are to be trained for early diagnosis of active TB differentiating its radiographic signs to that of inactive TB.²² In active primary TB, miliary opacities, pleural effusion which is common in adults, usually unilateral and homogenous opacities in middle and lower lobe mainly can occur, with or without lymphadenopathy referred to as Ghon complex (GC) while Ghon's focus (GF) - persistent calcification, tuberculoma (persistent mass like opacities) and fibrosis are findings of inactive TB.^{15,22} The

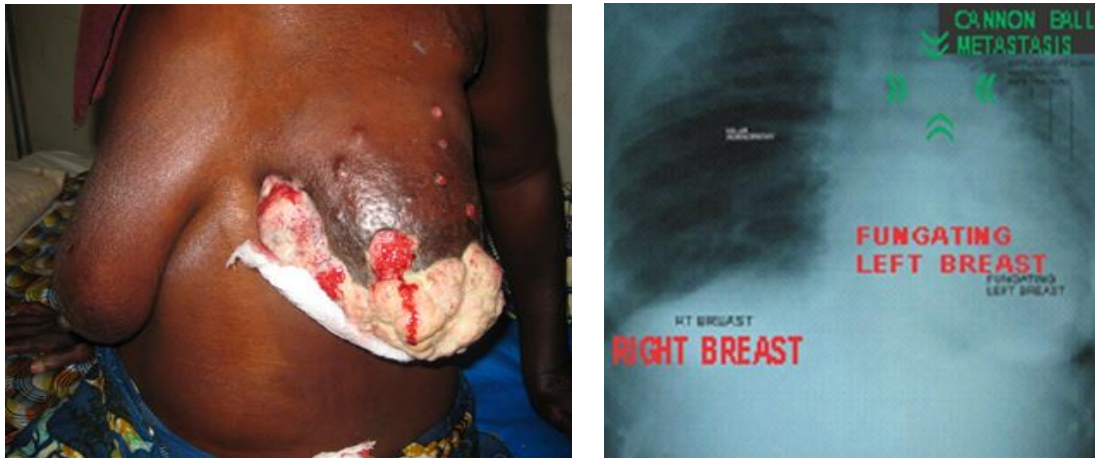


Figure 3: A female patient with advanced left breast carcinoma and metastasis to the left lung

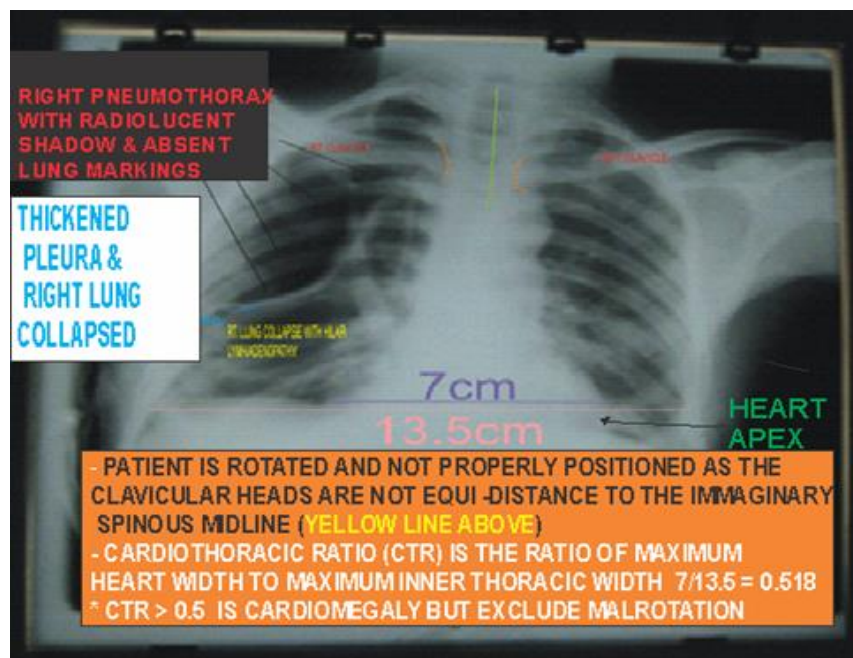


Figure 4: Chest X-ray P.A view with obvious patient rotation, pneumothorax, CTR

Ghon's focus occurs in upper part of lower lobe (95%) or apicoposterior segment of upper lobe. GC is GF with hilar lymphadenopathy.^{15,22} Secondary TB (post primary) presents with scars of fibronodular or fibrocalcific with lobar collapse, pleural thickening /pleural calcification and traction bronchiectasis.²² Nodular opacity > 3cm is termed a mass and can be

multiple; ring opacities has radiolucent center forming cavitation with inner and outer wall seen in preexisting TB lesion, pleural opacities from pleural effusion.¹⁵

g. Mediastinum – The mediastinum is the space between the two lung fields and is divided into anterior, middle and posterior mediastinum by the heart and its pericardium (middle mediastinum). Widened

Table 1: Advantages and disadvantages of chest X-ray

Advantages of chest X-ray		Disadvantages of chest X-ray
1	Widely available and accessible	Chest X-ray is not good for soft tissue evaluation though contrast enhancement may help
2	It is cheap compared to other imaging	Serial chest X-ray as seen in post chest tube insertion check x-rays carry more risk of radiation exposure
3	Ionizing dose is lower than CT scan. Organ dose for PA and lateral chest X-ray of the lungs is 0.01 and 0.15 mGy respectively. ⁵	Cannot be used for real time procedures like pace maker insertion
4	Films are now small and portable for easy carriage and a snap shot of chest X-ray film with others are communicated over to superiors/colleagues for review via WhatsApp for quick decision as a cheap avenue in our poor resource setting though privacy issue has to be looked into, but has helped saved patients in our environ. I coined it, IIMAC (Instant Internet Medical Apps Conferencing) which can involve other services like Zoom as well.	Digital teleradiology will make adoption slow in developing nations

- h. mediastinum can be caused by mass lesion (tumour, lymph nodes), inflammation (mediastinitis, trauma and dissection with haematoma and aneurysm of mediastinal vessels).²³ The trachea bifurcate at the carina and the carina angle ranges between 60 -100 degrees which is increased in left atrial enlargement, left upper lobe atelectasis and lymph node enlargement.²³ The CT ratio can depict heart enlargement. The heart size is less than half of the chest wall width. The apex of the heart is at the 6th left intercostal space (LICS). Remember the rare presence of the heart apex on the right side in dextrocardia. The cardiothoracic ratio (CTR) is defined as the ratio of the widest transverse dimension of the heart to the widest transverse dimension of the chest cavity measured to the inner surface of the ribs on posterior- anterior (PA) chest X-ray. It was first described in 1919.²⁴ Anterior-posterior (AP) radiograph increases the width of the heart closer to the chest wall. The

CTR should be presented as ratio and not percentage and range of normal

value is 0.42 to 0.5.²⁴ Values greater than 0.50 suggest cardiomegaly which can occur in heart failures and cardiomyopathies after first excluding other factors that leads to exaggeration of the cardiac size such as but not limited to rotation during filming as shown in figure 4. CTR is a prognostic factor in patients undergoing haemodialysis and those with rheumatic heart disease undergoing valve replacement, as a baseline CTR value greater than 0.6 is associated with perioperative hospitalization mortality and within the first year after valve replacement for the latter while the former has greater risk of cardiovascular and general mishap with high CTR.²⁴ Cardiomegaly can also be a feature of heart failure.

Pneumomediastinum – the presence of air in the mediastinum or thin rim of air around the heart.²⁴The

silhouette sign is loss of clarity of structures like heart and hemidiaphragm indicating adjacent shadows of soft tissue like lung consolidation.²⁴

CONCLUSION

Emergency physicians, trauma surgeons, pulmonologist, cardiologist and cardiothoracic surgeons, and general practitioners order a lot of imaging with Chest X-ray being topmost, in ascertaining immediate decision on patient management which has shown a reduced discrepancy to 1.1% from 45% with radiologist interpretation on quality assurance due to practice and training. However, this is not the case in our developing nation as more refresher is needed for all doctors and of particular are the medical officers running the hospitals in local governments of Nigeria. Hence, there is a need to reduce discrepancies in chest radiographic interpretation and reduce radiation risks to the patients.

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