الجامعة التقنية الوسطى
كلية التقنيات الصحية والطبية/ بغداد
قسم : قسم تقنيات الاشعة المرحلة: الرابعة
المادة: التصوير المقطعي المحوسب للصدر والبطن والحوض

Title: **العنوان:**

Computed Tomography of Cardiac and HRCT

Name of the instructor: **اسم المحاضر:**

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Target population: **الفئة المستهدفة:**

طلبة المرحلة الرابعة لكلية التقنيات الصحية والطبية في قسم تقنيات الاشعة

Introduction: المقدمة:

For many years, coronary angiography was the only method used to visualize the coronary arteries. Although effective, it is an invasive procedure associated with risks such as bleeding, stroke, myocardial infarction, and, in rare cases, death. It is also costly and requires recovery time after catheter removal. Therefore, coronary angiography is usually reserved for patients with severe symptoms or a high likelihood of significant coronary artery disease.

Advances in CT and magnetic resonance imaging (MRI) have changed cardiac imaging practice. Cardiac CT has emerged as a less invasive alternative for diagnosing coronary artery disease, particularly in low- and intermediate-risk patients. Improvements in CT detector technology, as well as temporal and spatial resolution, have enabled cardiac CT to achieve diagnostic results comparable to conventional coronary angiography.

Cardiovascular disease remains a leading cause of death, with coronary artery disease accounting for most cases. Cardiac CT provides both anatomical and functional information, supporting accurate diagnosis and clinical management.

A solid understanding of cardiac anatomy, physiology, and blood circulation is essential for technologists to produce high-quality cardiac CT images. This foundation allows effective application of technical parameters and imaging protocols used in cardiac CT examinations.

Pretest: الاختبار القبلي:

1. **Define the cardiac CT.**
2. **Mention the imaging protocols used in cardiac CT examinations**

Scientific Content: المحتوى العلمي:

Role and Indications

Cardiac computed tomography is widely used for the non-invasive evaluation of coronary artery anatomy and cardiac structures. One of its primary clinical indications is the assessment of suspected coronary artery disease, where it enables detailed visualization of the coronary arteries and their anatomical course. This capability supports the identification of coronary stenosis, plaque distribution, and anatomical variants.

Cardiac CT is also routinely applied for coronary artery calcium scoring, which provides quantitative assessment of coronary calcifications and assists in cardiovascular risk stratification.

In patients with previous coronary artery bypass surgery, Cardiac CT allows accurate evaluation of bypass graft patency, graft anatomy, and their relationship to adjacent cardiac and mediastinal structures.

In selected cases, Cardiac CT is utilized for the assessment of congenital cardiac anomalies, offering comprehensive anatomical information regarding cardiac chambers, great vessels, and abnormal connections. Additionally, Cardiac CT may be incorporated into general thoracic imaging examinations to provide anatomical assessment of the heart when clinically indicated.

The use of intravenous contrast material in Cardiac CT is determined by the specific diagnostic objective and protocol design, particularly in studies focusing on coronary arteries, graft evaluation, or detailed vascular anatomy.

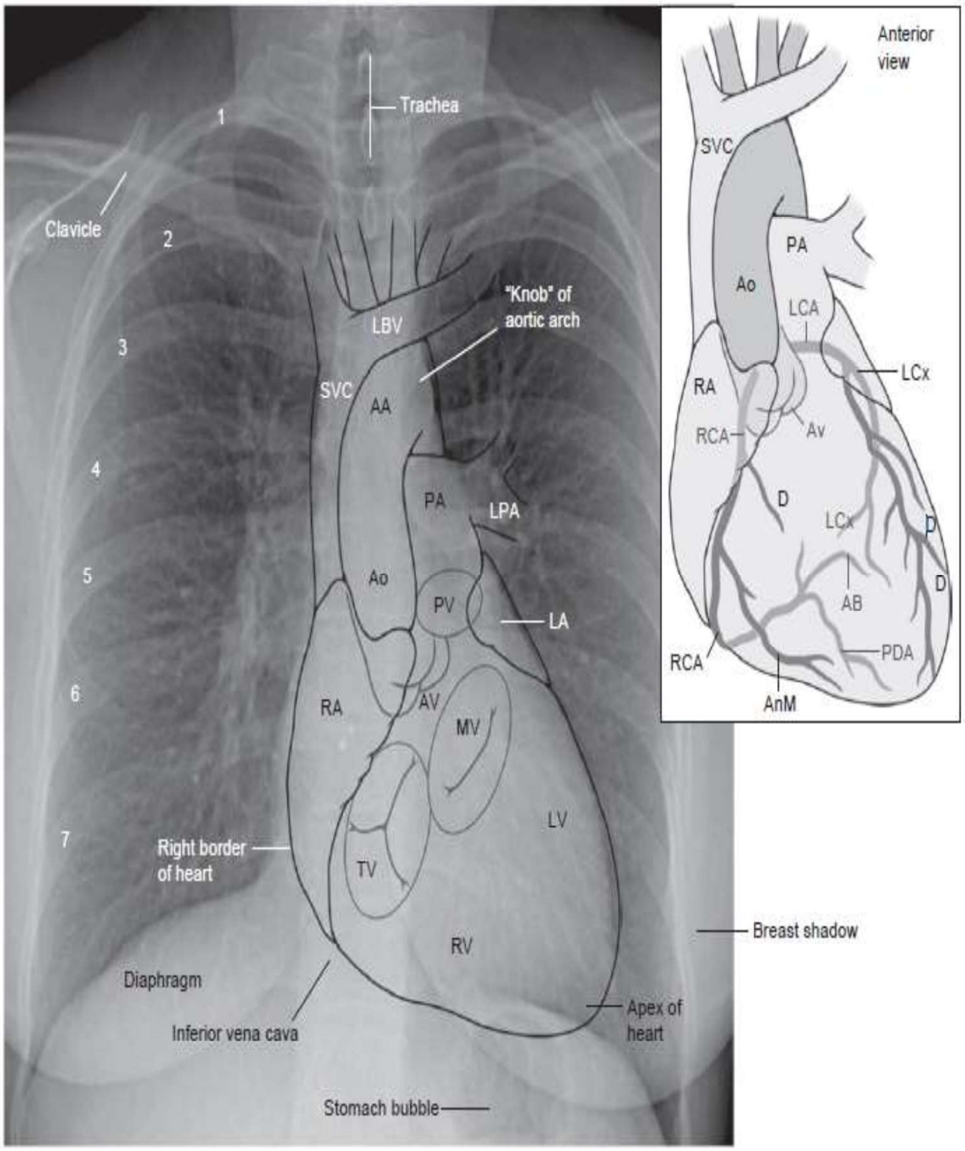
Overall, these applications highlight the versatility of Cardiac CT as a non-invasive imaging modality that contributes significantly to anatomical evaluation and clinical decision-making within thoracic and cardiovascular radiology.

CT Cardiac Anatomy

Cardiac computed tomography provides clear cross-sectional visualization of the heart and surrounding mediastinal structures. A solid understanding of normal cardiac anatomy on CT images is essential for technologist. On axial CT images, the heart is located within the mediastinum. The right ventricle typically forms the most anterior cardiac chamber, while the right atrium lies anterolateral on the right side. The left atrium is positioned most posteriorly, adjacent to the oesophagus. The left ventricle lies postero-laterally and forms the left cardiac border.

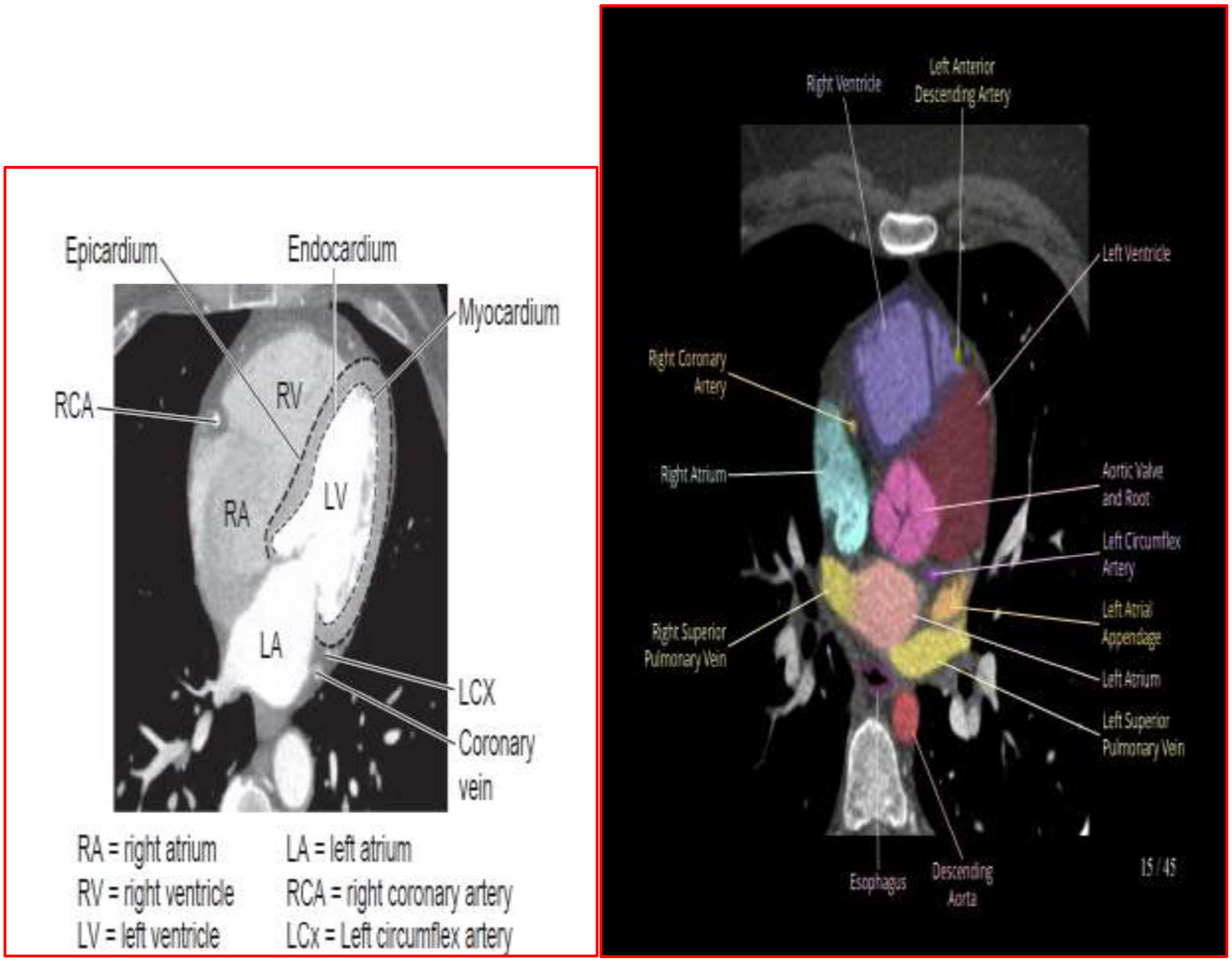
The ascending aorta and pulmonary trunk arise from the heart and course superiorly within the mediastinum, serving as important anatomical landmarks. The coronary arteries originate from the ascending aorta and follow characteristic anatomical pathways along the surface of the heart.

Multiplanar reformatted (MPR) images enhance anatomical assessment by allowing visualization of the heart in multiple planes and improving understanding of spatial relationships between cardiac structure. The technologist should remain familiar with the pattern of the heart circulation, coronary circulation, valves opening, cavities and the cardiac coverings.



LBV = left brachiocephalic v.
RA = right atrium
RV = right ventricle
LV = left ventricle
LA = left atrium
SVC = superior vena cava
AA = ascending aorta
Ao = aorta
PA = pulmonary a.
TV = tricuspid valve
MV = mitral valve
PV = pulmonary valve
AV = aortic valve
AB = atrial branch
AnM = acute marginal branch
RCA = right coronary a.
LCx = left circumflex a.
PDA = posterior descending branch
D = diagonal branches

Fig(1):The location of the heart in the thorax . Approximately tow third of the heart lies left of midline .the lower border of the heart lies on the diaphragm , pointed to the left known as the apex. The upper border of the heart is called the base and lies just below the second rib.



Fig(2) : The layers of the heart rate identified by arrows on the cross-sectional CT slice.

Cardiac CT Contraindications

Contraindications to Cardiac CT include several patient-related and procedural factors that may compromise patient safety or result in non-diagnostic image quality. One important consideration is the patient's ability to cooperate with the examination, as inability to follow breath-holding instructions or maintain proper arm elevation can lead to significant motion artefacts and inadequate image quality. In addition, contraindications related to pharmacological and contrast use must be carefully evaluated, including hypersensitivity or other contraindications to iodinated contrast media, nitrates, and β-blockers. Pregnancy, or uncertain pregnancy status in premenopausal women, represents a further contraindication due to the use of ionizing radiation and the potential risk to the developing foetus. These factors should always be assessed prior to the examination, with careful consideration of the clinical indication and potential alternative imaging modalities when appropriate.

Patient Preparation

Effective patient preparation for Cardiac CT begins with clear communication between the technologist and the patient. The examination procedure is explained in advance to ensure patient understanding and cooperation, which are essential for successful image acquisition. Clear communication helps reduce patient anxiety and improves compliance with breath-holding instructions and positioning throughout the examination.

Fasting prior to the Cardiac CT examination may be advised according to institutional protocol and clinical considerations. This preparation step helps minimize physiological interference and supports a smoother and more controlled examination process.

Ct Protocols and positioning

Technique General-purpose CT protocols can often be used in imaging of abdominal, thoracic, and cerebral vessels in which image quality is not substantially influenced by cardiac motion or vessel pulsation. However, for studies of the heart and coronary arteries, dedicated cardiac CT acquisition techniques are needed to produce images free of motion artifact. In addition, care must be taken with the delivery of contrast medium to ensure optimal enhancement of the targeted structure and the surrounding tissues. Visualization of the coronary arteries, a major application of cardiac CT, is difficult because the coronary arteries are of relatively small caliber, are often tortuous in shape, and are subject to constant, often rapid, heart motion. These challenges can be largely overcome by advances in MDCT technology that have improved both spatial and temporal resolution. Additionally, two other strategies are used to decrease cardiac motion artefacts. First, the patient's heart rate can be temporarily lowered by the administration of b-blockers. Second, a technique called cardiac gating attempts to use only those images acquired during periods of lowest cardiac motion. The patient is positioned supine on the CT table, with the head entering the gantry first unless otherwise required by institutional protocol. Correct positioning ensures accurate ECG synchronization, uniform image acquisition, and patient comfort throughout the examination. Both arms are raised above the head and secured The shoulders should be relaxed, and the patient's body should be aligned straight along the longitudinal axis of the table. Care is taken to centre the heart within the scanner's field of view, typically at the level of the mid-thorax.

Pharmacologic Heart Rate Control

Although modern CT scanners function as very fast imaging systems, excessive cardiac motion can still degrade image quality when the heart rate is high. For this reason, β-blockers are commonly incorporated into cardiac CT protocols to reduce the heart rate, typically to below 65–70 beats per minute, and to promote a more regular cardiac rhythm.
With continued improvements in CT temporal resolution, the dependence on pharmacologic heart rate control may decrease in the future. However, at present, β-blockers remain an important tool in many institutions.
Administration protocols may include oral, intravenous, or combined routes, and appropriate clinical guidelines must be followed to minimize complications. Metoprolol tartrate is the most frequently used agent, although alternatives such as atenolol, bisoprolol, betaxolol, acebutolol, and esmolol are also used. Oral β-blockers typically take

effect within one hour, whereas intravenous metoprolol reaches peak effect within 5–10 minutes.
Contraindications include sinus bradycardia (heart rate < 60 bpm), hypotension, drug allergy, decompensated heart failure, active bronchospasm, asthma requiring β-agonist inhalers, and advanced atrioventricular block. The decision to administer β-blockers and determine dosage is the responsibility of the physician and falls outside the technologist's scope of practice. These protocols are provided to support technologists in assisting radiologists during cardiac CT examinations.

Technologist Workflow in β-Blocker

The CT technologist plays an important supportive role in the workflow of β-blocker administration for Cardiac CT examinations. Before the examination, the technologist verifies whether the patient is already receiving β-blocker therapy and confirms the physician's instructions regarding medication use on the day of the scan. The patient's baseline heart rate is measured and documented to determine the need for pharmacologic heart rate control.
During pre-scan preparation, patients are typically assessed one hour before image acquisition to allow adequate time for heart rate management if required. When the heart rate exceeds the institutional threshold, the technologist assists with oral β-blocker administration as prescribed and observes the patient for appropriate response and tolerance, while ensuring adherence to clinical guidelines.
Immediately before scanning, the technologist reassesses the heart rate to confirm suitability for image acquisition. If the heart rate remains elevated, intravenous β-blocker administration may be performed under physician direction, with the technologist providing monitoring and support during administration. Continuous observation of heart rate, rhythm, and patient condition is essential at this stage.
Throughout the examination and following image acquisition, the technologist continues patient monitoring to detect any adverse reactions or changes in clinical status. All medication administration, heart rate measurements, and relevant observations are documented accurately and communicated to the radiologist or supervising physician to ensure patient safety and optimal diagnostic image quality.

Image Acquisition and ECG Synchronization

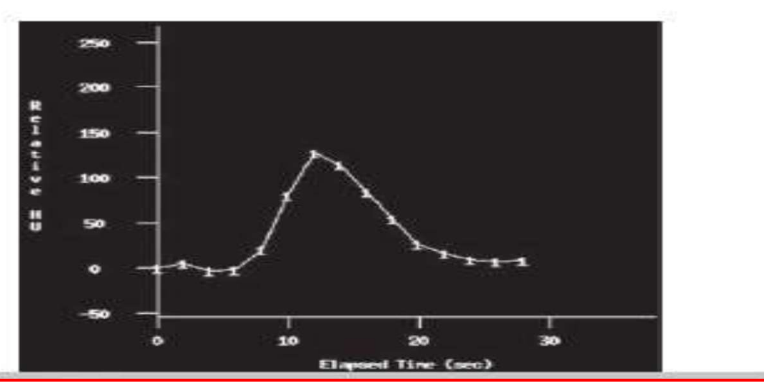
Electrocardiographic (ECG) synchronization is a fundamental component of Cardiac CT imaging, enabling coordination between image acquisition and the cardiac cycle. Because the heart is in continuous motion, ECG synchronization helps reduce motion-related artifacts by timing data acquisition to relatively motion-stable phases of the cardiac cycle. This improves visualization of cardiac chambers and coronary arteries and supports consistent image quality.
Two conceptual approaches are used for ECG synchronization. Prospective ECG triggering, and retrospective ECG gating flexible. ECG synchronization influences image quality, motion artifacts, and radiation considerations in Cardiac CT examinations.

Image Reconstruction Parameters and Window Settings

Image interpretation in Cardiac CT relies on appropriate reconstruction parameters and display settings. Images are typically reconstructed using thin-section data to allow detailed assessment of cardiac anatomy and coronary arteries, while thicker reformatted images may be used for overview and post-processing. Review of Cardiac CT images is performed using dedicated cardiac and coronary window settings, which optimize visualization of vascular structures and myocardial borders.

Contrast Administration

Most Cardiac CT examinations require intravenous injection of an iodinated contrast agent to achieve clear visualization of the heart and coronary arteries. Prior to contrast administration, patients are screened for contraindications such as renal impairment or iodine allergy to ensure safety. A large-bore intravenous cannula is typically placed in the antecubital vein, preferably on the right side. Low- or iso-osmolar nonionic contrast agents with iodine concentrations of 300–380 mg/mL are injected at high flow rates, usually between 3 and 6 mL/s, with total contrast volumes ranging from approximately 70 to 150 mL depending on the protocol, scanner type, and patient body weight. Accurate timing of image acquisition is essential and must be individualized for each patient, as contrast arrival to the coronary arteries is influenced by factors such as cardiac output, ejection fraction, and pulmonary or cardiac disease. Optimal scan timing is achieved using either the timing bolus techniques like a time–density curve, or the bolus tracking technique, where image acquisition is triggered automatically once contrast enhancement in a selected region of interest reaches a predefined threshold, commonly around 150 HU. The ROI location depends on the clinical indication, with the ascending aorta used for coronary artery imaging and the left atrium for pulmonary vein evaluation. Immediately following contrast injection, a saline flush is administered to push residual contrast into the circulation, improve enhancement uniformity, reduce required contrast volume, and minimize streak artefacts.



Fig(3): Timing bolus software calculates the delay between the start of the contrast injection and when the contrast beaks in the ascending aorta.

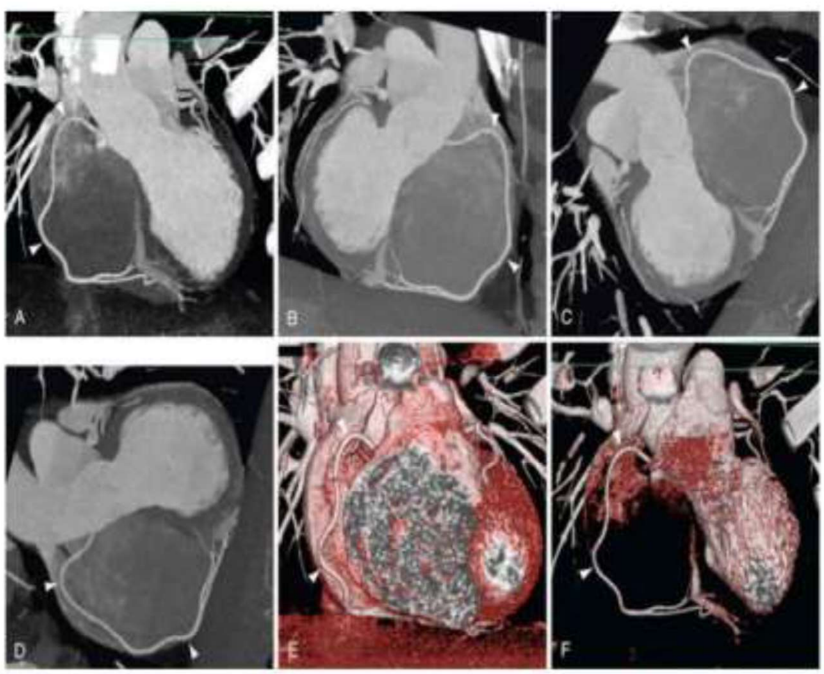
Calcium scoring Screening

Atherosclerosis involves the accumulation of fat, plaque, and calcium within the arterial wall and is a key feature of CAD. Coronary artery calcification is an established marker of CAD, and many affected patients may remain asymptomatic, with myocardial infarction sometimes being the first clinical sign. The aim of CT coronary calcium screening is to detect and quantify calcified plaque within the coronary arteries, allowing estimation of future cardiovascular risk in asymptomatic individuals.

Coronary calcification on cardiac CT is reported as a calcium score, most commonly using the Agatston method. A negative examination and A positive calcium score should assists in cardiovascular risk evaluation.

Image Display and Post-Processing

Cardiac CT images are reviewed using a combination of axial images, multiplanar reformations (MPR), and three-dimensional (3D) reconstructions. Axial images provide the primary cross-sectional view of cardiac structures, while MPR images allow evaluation of the heart in different planes, improving understanding of anatomical relationships between cardiac chambers and vessels. Three-dimensional reconstructions offer a comprehensive anatomical overview and are particularly useful for educational purposes and visualization of complex cardiac anatomy. Together, these post-processing techniques enhance interpretation and presentation of Cardiac CT images.



A-F, This set of images shows the relative utilities of each rendering technique. **A-D,** The proper study protocol has yielded a clear view of the right coronary artery (arrowheads) with MIP imaging, but with MIP it is hard to be certain that one is actually imaging the origin of the right coronary artery. **E** and **F,** With VRT, this is not an issue, and the color-coded VRT images provide a better three-dimensional perspective. The VRT images are the same projection, but use different rendering parameters.

Fig(4): Its show the relative utilities of each rendering techniques

Common Cardiac CT Findings

Cardiac CT can demonstrate a wide range of anatomical appearances based on high-resolution morphological imaging of the heart. Coronary artery calcifications may be visualized as areas of increased attenuation within the vessel walls, reflecting structural changes rather than functional impairment. Variations in coronary artery anatomy, including differences in vessel origin or anatomical course, may also be identified and generally represent normal anatomical diversity. Cardiac CT may show apparent enlargement of cardiac chambers, which should be interpreted in relation to the image acquisition phase, cardiac motion, and reconstruction orientation. In addition, motion-related image appearances can influence the visualization of coronary arteries and cardiac structures, potentially altering their perceived contour or continuity. Accurate recognition of these findings requires careful morphological assessment and an understanding of imaging-related factors, emphasizing the role of Cardiac CT as an anatomical imaging modality rather than a primary tool for functional evaluation.

Advantages and limitations

Cardiac CT offers several important advantages in cardiac imaging. It is a non-invasive technique that provides high-resolution visualization of cardiac anatomy and coronary arteries. The ability to obtain detailed anatomical information makes Cardiac CT a valuable adjunct to other cardiac imaging modalities and an important component of comprehensive thoracic imaging. Despite its advantages, Cardiac CT has certain limitations. Continuous cardiac motion may influence image quality, and optimal results depend on effective patient cooperation during the examination. Considerations related to radiation exposure are also important in cardiac imaging.

HRCT

High-Resolution Computed Tomography is a specialized chest CT technique optimized to produce images with high spatial resolution. HRCT uses thin-section image acquisition and high-resolution reconstruction algorithms to enhance the depiction of fine anatomical details within the lungs.

Indications of chest CT

In the acute setting, chest CT plays a crucial role in the assessment of chest trauma, allowing accurate evaluation of thoracic injuries and associated complications. It is also a key imaging modality for the evaluation of acute aortic syndromes, including aortic dissection and aortic transection. CT pulmonary angiography is routinely performed for the detection of pulmonary embolism. In addition, chest CT is used to identify postoperative complications following thoracic surgery, such as mediastinal hematomas and complex pleural collections. During infectious outbreaks, including COVID-19, chest CT may be utilized to assess pulmonary involvement and disease extent when clinically indicated. In the non-acute setting, chest CT is commonly performed for further evaluation of abnormalities detected on chest radiography, such as pulmonary nodules and hilar or mediastinal masses. It is an essential imaging tool in the diagnosis and staging of lung

cancer. Chest CT is also used in the assessment of congenital anomalies of the thoracic great vessels. Furthermore, chest CT is widely employed for the detection of pulmonary metastases in patients with known extra-thoracic malignancies. In the High-resolution CT is primarily indicated for detailed evaluation of lung parenchyma. High-resolution CT is primarily indicated for detailed evaluation of lung parenchyma. It plays a central role in the assessment and characterization of interstitial lung diseases by enabling identification of specific parenchymal patterns and disease distribution. HRCT is designed to evaluate pulmonary microanatomy, including the interstitium, airways, and secondary pulmonary lobules, rather than to provide a general overview of thoracic, mediastinal, or vascular structures. Consequently, HRCT is particularly valuable for precise morphological assessment of lung architecture and subtle parenchymal abnormalities.

Contraindications of HRCT

High-resolution CT has relatively few absolute contraindications; however, several factors should be considered before performing the examination to ensure patient safety and diagnostic usefulness. HRCT is generally avoided in pregnant patients unless the potential clinical benefit clearly outweighs the risk, due to exposure to ionizing radiation. In addition, patients who are unable to cooperate, particularly those who cannot follow breath-holding instructions or remain still, may produce motion-degraded images that limit diagnostic value. HRCT should also be used cautiously in patients requiring repeated follow-up examinations, as cumulative radiation dose may become a concern, especially in younger patients. Although HRCT is usually performed without intravenous contrast, clinical judgment is required to ensure that HRCT is appropriately indicated, as it is not suitable for the evaluation of vascular, mediastinal, or cardiac conditions. Therefore, patient selection and adherence to proper indications are essential to maximize diagnostic benefit while minimizing unnecessary radiation exposure.

HRCT Examination and Patient Preparation

High-resolution CT examination focuses primarily on the lungs, Traditionally, HRCT employed non-contiguous sampling to obtain representative images of lung parenchyma; however, modern multidetector CT systems allow volumetric thin-section acquisition of the entire lungs. Patient preparation for HRCT is minimal and is mainly dependent on patient cooperation. Clear information about the procedure is provided in advance, with particular emphasis on breath-holding instructions, and metallic objects are removed from the chest region to avoid image artifacts. A frontal scout radiograph is obtained from the lung apex to the lung base. The patient is positioned supine with the arms elevated above the head. The volume of investigation extends from the lung apex to the lung base in cases of diffuse lung disease, or is limited to radiographically defined abnormalities in localized disease. Nominal slice thickness is typically 1–2 mm, with image acquisition performed either in a non-contiguous manner or as a volumetric scan depending on scanner technology. The field of view is adjusted to the minimum required to include the entire lung field, and gantry tilt is not used. Tube voltage is selected at standard levels according to patient size, while tube current is kept as low as reasonably achievable to maintain adequate image quality. Images are reconstructed using a high-resolution algorithm. Lung window settings are typically applied, with a window width of approximately 1000–1600

HU and a window level of –400 to –700 HU. Common technical challenges include motion artifacts due to dyspnoea and dependent atelectasis, which may obscure underlying pulmonary pathology.

Normal Lung Anatomy on HRCT

On HRCT images, normal lung parenchyma appears as a fine, uniform pattern with visible bronchovascular structures. The secondary pulmonary lobule can be appreciated as the basic functional unit of the lung. Interlobular septa are typically thin and may not be prominent in normal lungs. Airways and pulmonary vessels are visualized as branching structures extending from the central to peripheral lung regions.

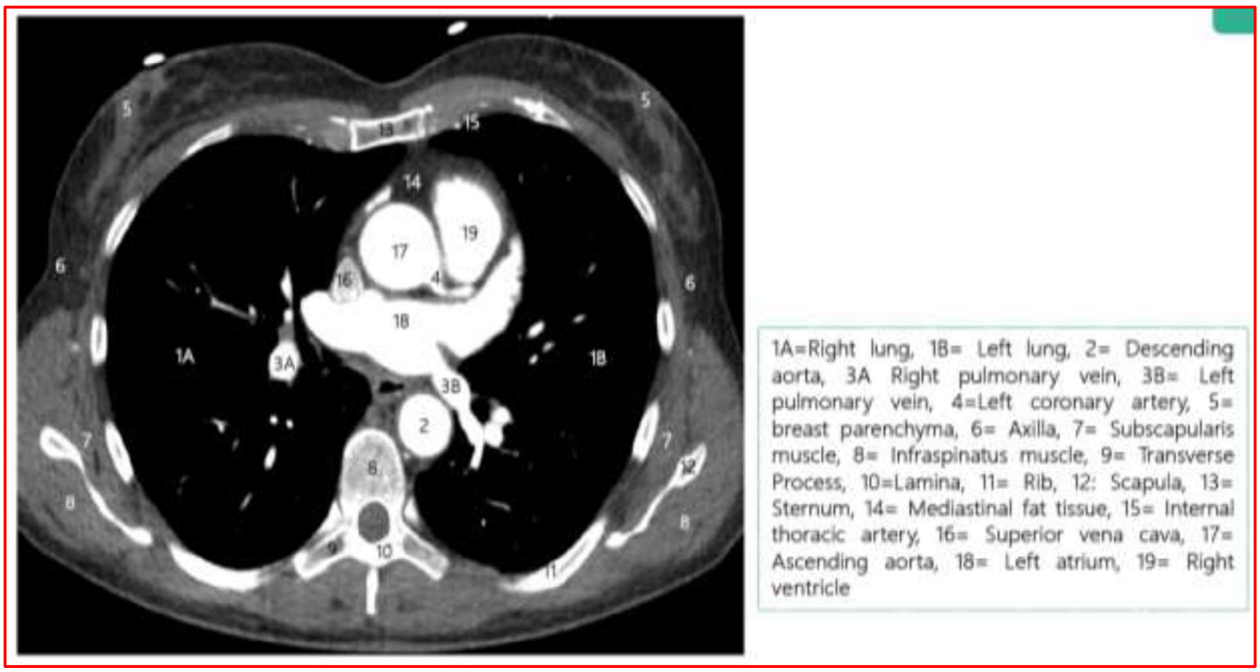


Fig (5):Cross sectional anatomy of chest

Image Display and Windowing

HRCT images are primarily reviewed using lung window settings to enhance visualization of pulmonary parenchyma. Mediastinal window images may be reviewed for anatomical reference but are not the primary focus of HRCT evaluation. Proper windowing allows clear demonstration of lung texture and subtle parenchymal changes.

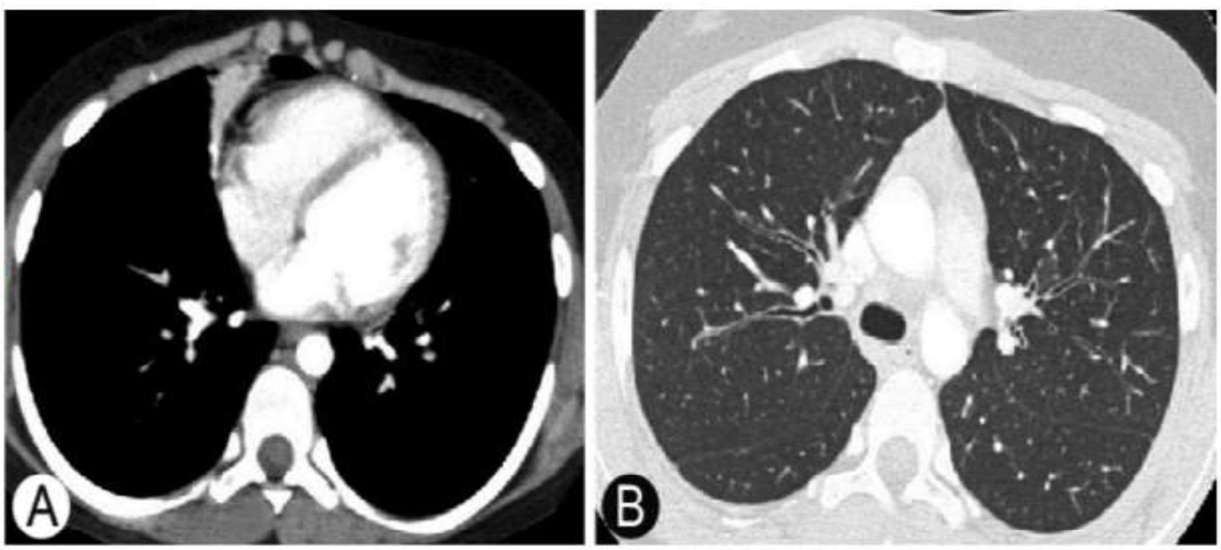
Common HRCT Patterns

HRCT allows visualization of characteristic lung patterns based on structural appearance.

Commonly demonstrated patterns include:

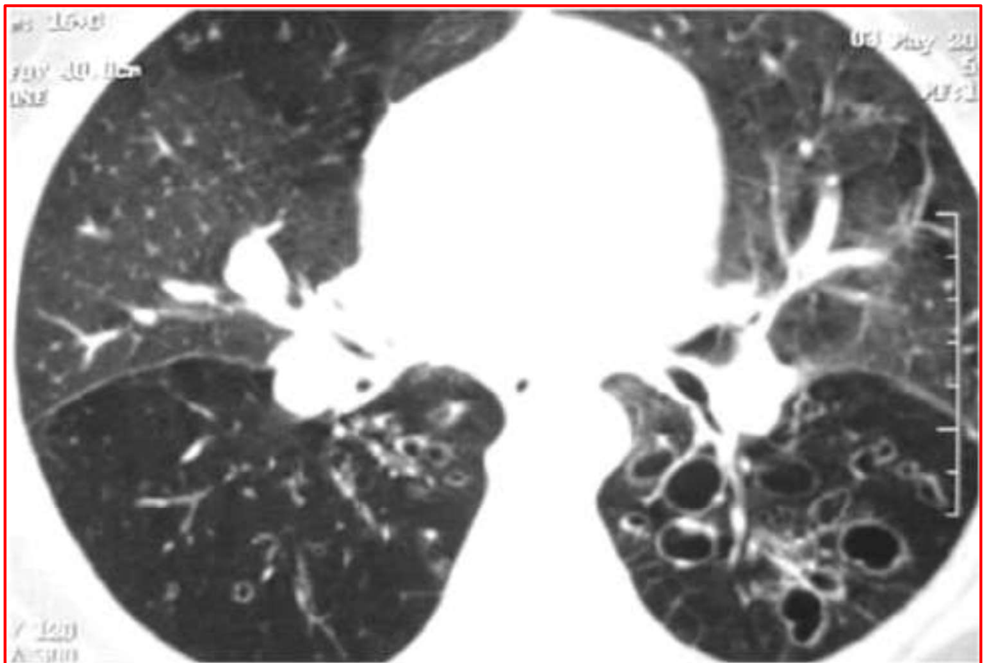
- **Ground-glass opacity, representing areas of increased lung attenuation without obscuration of underlying structures**
- **Reticular pattern, showing linear opacities related to interstitial involvement**
- **Honeycombing, characterized by clustered cystic air spaces in advanced lung disease**
- **Air trapping, visible as areas of decreased attenuation**

- **Inspiratory and Expiratory Imaging**
- **HRCT examinations may include images acquired during different phases of respiration. Inspiratory images provide optimal visualization of lung parenchyma, while expiratory images may demonstrate air trapping and small airway disease.**



(A) High resolution computed tomography (HRCT) (mediastinal window) of the thorax showing middle lobe syndrome. (B) HRCT (lung window) of the thorax showing central bronchiectasis.

Fig (6):Both A&B images of high resolution computed tomography



HRCT chest axial image lung window shows right lower lobe signet ring sign and left lower lobe cystic bronchiectasis. Marked oligemia denoting bronchiolitis obliterans in case with post inflammatory bronchiectasis.

Fig (7): high resolution computed tomography chest axial image show lung window.

Limitations of HRCT

Despite its advantages, HRCT has limitations. Image interpretation depends on patient cooperation during breath-holding, and subtle motion can affect image quality. HRCT provides anatomical information but does not directly assess lung function.

Posttest: الاختبار البعدي:

1. **Mention the contraindication of the cardiac CT?**
2. **Mention the imaging protocols used in cardiac CT examinations?**
3. **What is the calcium scoring Screening ?**
4. **Enumerate the indication & contraindication of the HRCT?**

References: المصادر:

References

1. **Romans, L. E. *Computed Tomography for Technologists: Exam Review*. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2011.**
2. **Seeram, E. *Computed Tomography: Physical Principles, Clinical Applications, and Quality Control*. 4th ed. St. Louis: Elsevier; 2016.**
3. **Hofer, M. *CT Teaching Manual: A Systematic Approach to CT Reading*. Stuttgart: Thieme; 2010.**