# Shri Ramdeobaba College of Engineering & Management, Nagpur

Department of Electronics and Communication Engineering

Subject Name:- Biomedical Equipment: Repairing & Maintaining Biomedical Devices

$6^{th}$ Semester B.Tech. Session-2023-24

Project Report

On

The Topic

"Computed Tomography"


Name: - Narendra Rajkumar Dhakate

Roll No: - 42

Section :- A

Year:- $3^{rd}$

Sem:- $6^{th}$

Branch: - Electronics and Communication


Date of Submission: - 09/01/2024

Course Coordinator

Ms. Prachi Vyas

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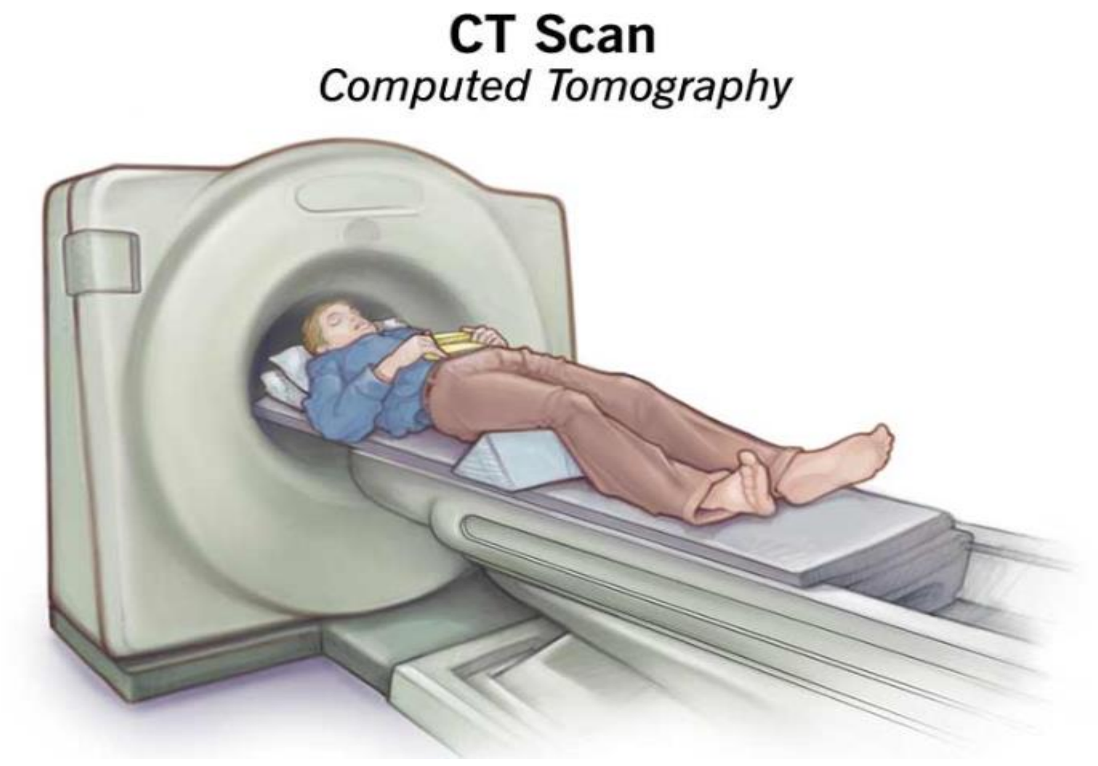
## TITLE OF THE REPORT: - "COMPUTED TOMOGRAPHY"

## INTRODUCTION: -

Computed Tomography (CT), a cornerstone in modern medical diagnostics, stands as a testament to the convergence of cutting-edge technology and healthcare. Computed tomography (CT), sometimes called "computerized tomography" or "computed axial tomography" (CAT), is a non-invasive medical examination or procedure that uses specialised X ray equipment to produce cross-sectional images of the body. Each cross-sectional image represents a "slice" of the person being imaged, like the slices in a loaf of bread. These cross-sectional images are used for a variety of diagnostic and therapeutic purposes. As an expert in this field, it is evident that CT has revolutionized diagnostic capabilities by providing clinicians with unprecedented insights into the internal structures of the body. The ability to generate high-resolution, cross-sectional images swiftly and with remarkable accuracy has made CT an indispensable tool in the identification and characterization of diverse medical conditions, ranging from tumors and trauma to vascular anomalies. This introduction sets the stage for a deeper exploration of the principles, applications, and considerations that define the realm of Computed Tomography. CT scans can be performed on every region of the body for a variety of reasons (e.g., diagnostic, treatment planning, interventional, or screening). Most CT scans are performed as outpatient procedures.



# DESIGN AND COMPONENTS:-

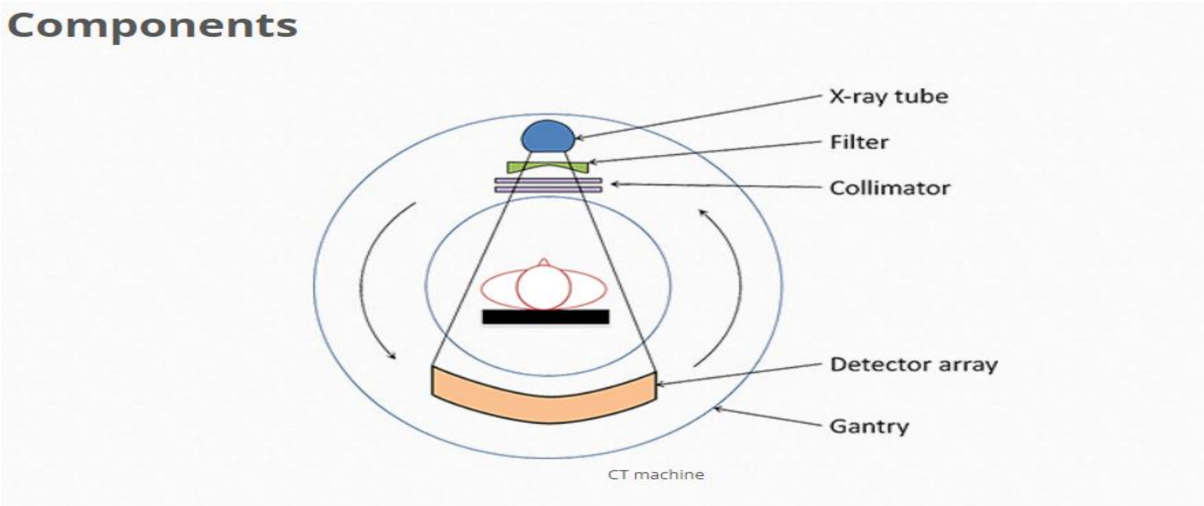



Fig No 1: COMPONENTS

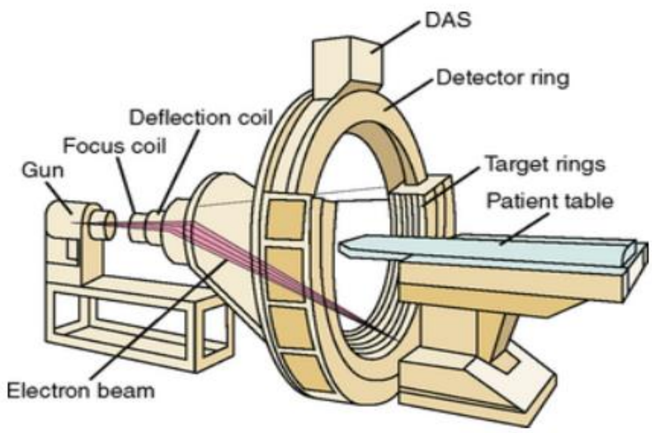
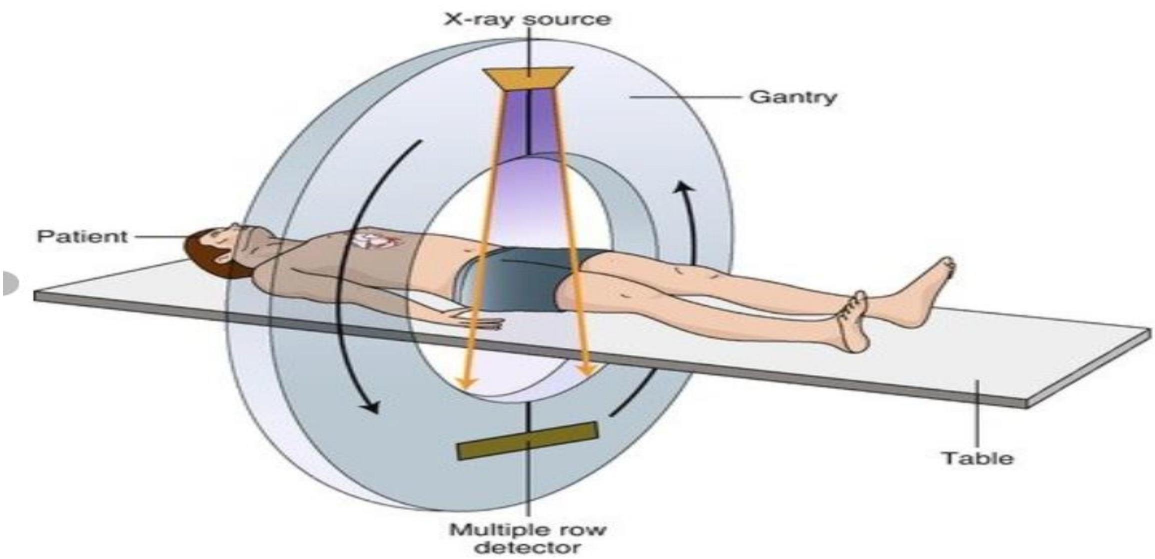



Fig No 2: DESIGN



1) Gantry:
Description: The gantry is the circular structure that houses the essential components of the CT scanner.
Function: It rotates around the patient during the scanning process, allowing X-rays to pass through the body from different angles.

2) X-ray Source:
Description: This is where the X-rays are generated.
Function: The X-ray source emits a series of narrow beams that pass through the body. These X-rays are essential for capturing images of the internal structures.

3) Detector Array:
Description: Positioned opposite the X-ray source, the detector array forms a ring within the gantry.
Function: Detectors measure the intensity of X-rays that traverse the body. The data collected is crucial for creating detailed cross-sectional images during image reconstruction.

4) Filter:
Description: Placed between x-ray source and patient.
Function: Removes low energy x-rays. Produces a more monochromatic beam. May be bowtie-shaped to even out attenuation once it passes through the body.

5) Patient Table:
Description: A flat table on which the patient lies during the CT scan.
Function: The table moves through the gantry, aligning the specific body part being scanned with the X-ray beam. Precise table movement ensures accurate imaging of the targeted area.

6) Control Panel:
Description: A user interface for the technologist or radiologist to operate the CT scanner.
Function: The control panel allows for the selection of scan parameters, such as scan type, slice thickness, and other settings, ensuring customization based on the diagnostic requirements.

7) Computer System:
Description: The computer system processes and analyzes the data acquired during the scan.
Function: It performs intricate mathematical calculations for image reconstruction. The computer interprets the information from the detector array to create detailed cross-sectional images of the scanned area.

8) Display Monitor:
Description: A screen where the reconstructed images are displayed.
Function: Radiologists use the monitor to visualize and interpret the images, aiding in the diagnosis of medical conditions.

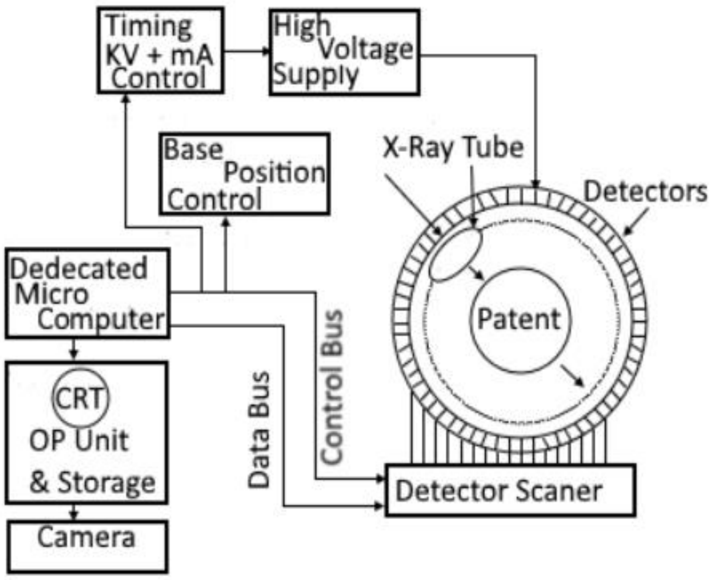
9) Power Supply:
   Description: The CT scanner requires a stable power supply for all its components.
   Function: A reliable power supply ensures the continuous and accurate operation of the X-ray source, detector array, computer system, and other essential elements.

10) Collimators:
   Description: Adjustable devices within the X-ray beam path.
   Function: Collimators help control the size and shape of the X-ray beam, allowing for precise targeting of the region of interest and minimizing unnecessary radiation exposure.

11) Data Acquisition System (DAS):
   Description: DAS is responsible for converting analog signals from the detectors into digital data.
   Function: It plays a crucial role in collecting and digitizing the measurements obtained by the detector array, facilitating subsequent computer processing and image reconstruction.

12) Cooling System:
   Description: The cooling system prevents components, particularly the X-ray tube, from overheating.
   Function: Continuous operation of the CT scanner generates heat, and the cooling system ensures that the components remain within optimal temperature ranges, promoting longevity and reliability.

## BLOCK DIGRAM EXPLANATION:



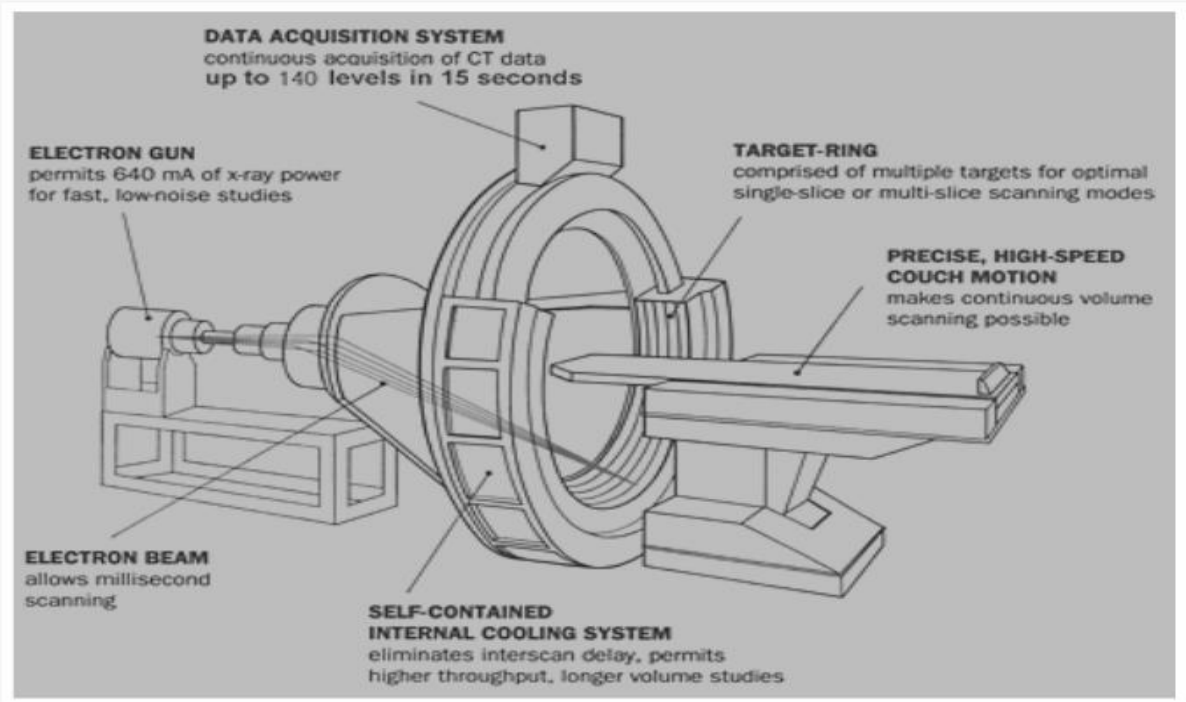

Block Diagram of CT Scanner

Fig:- Block Diagram

1) High voltage supply drives the X-ray tube that can be mechanically rotated along the circumference of a gantry.
2) The patient is lying in a tube in the center of the gantry.
3) The X-rays pass through the patient and produce an image on detectors, which are fixed in a place around the circumference of the gantry in a large quantity.
4) The microcomputer senses the position of the tube in the gantry and samples the output of the detector scanner which is opposite to the X-ray tube.
5) A calculation based on the data of a computer scan of the tube is made by the computer.
6) The output unit then produces a visual image of a transverse plane across the section of the patient.
7) Output may be displayed on the cathode ray tube or photographed with a camera to produce a hard copy record.

## WORKING OF ELECTROLYTE ANALYZER:-

CT uses X rays to scan the body parts. CT produces a volume of data which can be manipulated, through a process known as "windowing", in order to demonstrate various bodily structures based on their ability to block the X-ray beam. Formerly the images generated were in the axial or transverse plane, orthogonal to the long axis of the body, the new CT scanners allow this volume of data to be reformatted in various planes or even as volumetric (3D) representations of structures. X beam having 1.5 to 5.8 mSv effective dose is used in CT. The image of the various sections of the body parts such as brain can be observed in the computer monitor or can be photographed.




**CT Scanning:**

CT can be used for detecting both acute and chronic changes in the lung parenchyma of the lungs. It is particularly relevant because normal two-dimensional x-rays do not show such defects.

**CT Angiography:**

CT angiography of the chest is also becoming the primary method for detecting pulmonary embolism. CT is the standard method of evaluating abnormalities seen on chest X-ray and of following findings of uncertain acute significance. Cardiac CTA is now being used to diagnose coronary artery disease. CT pulmonary angiogram (CTPA) is the test used to diagnose pulmonary embolism. Images are usually taken on a 0.625 mm slice thickness, although 2 mm is sufficient. 50–100 ml of contrast is given to the patient at a rate of 4 ml/s.

**ECG Grating:**

In ECG gating, each portion of the heart is imaged more than once while an ECG trace is recorded. The ECG is then used to correlate the CT data with their corresponding phases of cardiac contraction. Once this correlation is complete, all data that were recorded while the heart was in motion (systole) can be ignored and images can be made from the remaining data that happened to be acquired while the heart was at rest (diastole). In this way, individual frames in a cardiac CT investigation have a better temporal resolution than the shortest tube rotation time.

**Abdominal Scanning:**

CT is a sensitive method for diagnosis of abdominal diseases. It is used frequently to determine the stage of cancer and to follow progress. It is also a useful test to investigate acute abdominal pain, Renal stones, appendicitis, pancreatitis, diverticulitis etc. CT is also the first line for detecting solid organ injury after trauma.

## TYPES OF COMPUTED TOMOGRAPHY: -

Computed Tomography (CT) technology has evolved over the years, leading to different types of CT scanners that cater to various clinical needs and applications. The main types of CT scanners include:

**1. Single-Slice (1st Generation) CT:**

Description: The earliest form of CT technology introduced in the 1970s.
Features: Captures a single slice or image per rotation.
Limited speed and resolution compared to modern scanners.
Applications: Basic anatomical imaging.
Advantages: Pioneering technology, foundational for later developments.
Lower cost compared to more advanced systems.

**2. Multi-Slice CT:**

Description: Introduced in the 1990s, these scanners capture multiple slices in a single rotation.
Features: Simultaneously acquires multiple slices, typically 4, 16, 64, or more.
Higher speed and improved image resolution.
Applications: Rapid imaging for detailed anatomical studies. Enhanced vascular and cardiac imaging.
Advantages: Increased efficiency in data acquisition. Enables advanced applications like cardiac CT angiography.

**3. Cone-Beam CT:**

Description: Utilizes a cone-shaped X-ray beam for specialized imaging applications. Features: Commonly used in dental and orthopedic imaging. Acquires a volumetric dataset in a single rotation. Applications: Dental implant planning and Musculoskeletal imaging. Advantages: Lower radiation dose for specific applications. Suitable for smaller anatomical regions.

**4. Photon-Counting CT:**

Description: An emerging technology utilizing photon-counting detectors. Features: Detects individual photons, allowing for improved energy discrimination. Potential for better dose management and improved image quality. Applications: Currently in research and development stages. Advantages: Potential for reduced radiation dose. Enhanced tissue characterization.

**5. Dual-Energy CT:**

Description: Capable of acquiring images at two different X-ray energy levels. Features: Allows for material decomposition and improved tissue characterization. Enhances the ability to differentiate between different types of tissues. Applications: Virtual non-contrast imaging. Improved detection of specific materials (e.g., kidney stones). Advantages: Enhanced diagnostic information. Improved accuracy in material identification.

**6. Portable or Mobile CT:**

Description: Compact and mobile CT units designed for point-of-care or bedside imaging. Features: Used in emergency rooms, intensive care units, and during surgical procedures. Provides immediate imaging without the need for patient transport. Applications: Trauma imaging, Bedside diagnostics. Advantages: Increased accessibility in critical care settings. Reduced time for urgent imaging studies.

Understanding these different types of CT scanners allows for a tailored approach to medical imaging, considering factors such as clinical requirements, patient conditions, and specific diagnostic goals. The continuous advancements in CT technology contribute to improved diagnostic capabilities and patient care.

## ACCURACY:-

The accuracy of CT imaging is paramount for precise diagnosis and treatment planning. It depends on factors like spatial resolution, contrast resolution, and temporal resolution. Modern CT scanners exhibit exceptional accuracy, with sub-millimeter spatial resolution, enabling the detection of minute anatomical structures and abnormalities.

Advanced Technological Features Enhancing Accuracy:

Dual-Energy-CT:
Explanation: Dual-energy CT utilizes two different X-ray energy levels to provide material-specific information. Impact: This feature enhances accuracy by differentiating between different tissue types based on their unique energy absorption characteristics, offering improved characterization of lesions.

Iterative-Reconstruction-Algorithms:
Explanation: Iterative reconstruction algorithms are advanced computational techniques that refine image quality during the reconstruction process.
Impact: By reducing image noise and artifacts, these algorithms contribute to higher image fidelity, leading to improved accuracy in interpreting CT images.

## CALIBRATION:-

Calibration in computed tomography (CT) is a critical process that ensures the accuracy and reliability of the images produced by the CT scanner. Calibration involves a series of checks and adjustments to various components of the CT system, including the X-ray source, detectors, and other hardware. The goal is to maintain consistent and precise imaging parameters, which is essential for accurate diagnosis and treatment planning. Here's a detailed explanation of the calibration process in CT:

1. X-ray Source Calibration: Ensures the X-ray source emits a consistent and accurate intensity of X-rays.

2. Detector Calibration: Ensures that detectors accurately measure the intensity of X-rays passing through the patient.

3. Geometric Calibration: Ensures accurate spatial relationships and minimizes image distortion.

4. Image Calibration: Ensures pixel values in the reconstructed images correspond to the true attenuation values of the scanned materials.

5. Dose Calibration: Verifies the accuracy of the displayed radiation dose values.

6. Software Calibration: Ensures that the CT reconstruction algorithms and image processing software function accurately.

7.Regular Maintenance: Prevents drift in system performance over time.

## COMMON ISSUES AND TROUBLESHOOTING:-

Computed Tomography (CT) imaging, while highly valuable, can encounter various issues that may affect image quality and diagnostic accuracy. Addressing these issues through troubleshooting is crucial to maintaining the reliability of the CT system. Here's a detailed explanation of common issues in CT and the associated troubleshooting steps:

1. **Artifacts:**
   Description: Artifacts are unwanted patterns or distortions in CT images that can result from various factors such as patient motion, metallic objects, or scanner malfunctions.
   Troubleshooting:
   Motion Artifacts: Instruct patients to remain still during scans, and use immobilization devices if necessary.
   Metallic Artifacts: Adjust imaging parameters or use metal artifact reduction techniques.
   Scanner Calibration: Regularly calibrate the CT scanner to maintain image quality.

2. **Image Noise:**
   Description: Image noise appears as random variations in pixel intensity, reducing image clarity.
   Troubleshooting:
   Optimize Parameters: Adjust scan parameters such as mAs and kVp for the specific imaging task.
   Iterative Reconstruction: Utilize iterative reconstruction algorithms to reduce noise while preserving image details.

3. **Contrast Enhancement Issues:**
   Description: Inadequate contrast enhancement may occur, affecting the visibility of structures.
   Troubleshooting:
   Check Contrast Administration: Ensure proper contrast administration technique, including appropriate dose and injection rate.
   Monitor Injection System: Verify the functionality of the contrast injection system.

4. **Scanner Calibration Drift**:
   Description: Over time, CT scanners may experience calibration drift, leading to inconsistencies in image quality.
   Troubleshooting:
   Regular Maintenance: Implement a routine maintenance schedule, including calibration checks.
   Calibration Records: Keep comprehensive records of calibration procedures and results.

5. **Scanner Hardware Malfunctions:**
   Description: Mechanical or electrical issues in the scanner components can disrupt image acquisition.

Troubleshooting:
System Diagnostics: Utilize built-in diagnostic tools to identify hardware malfunctions.
Service Support: Engage technical support for timely repairs and preventive maintenance.

6. **Dose-related Concerns:**
Description: Radiation dose considerations are critical for patient safety and regulatory compliance.
Troubleshooting:
Dose Monitoring: Implement dose monitoring tools to track and optimize radiation exposure.
Dose Reduction Strategies: Explore and apply dose reduction techniques without compromising image quality.

7. **Software Glitches:**
Description: Software errors or glitches can impact image reconstruction and processing.
Troubleshooting:
Software Updates: Ensure the CT software is up-to-date with the latest patches and upgrades.
Technical Support: Consult the vendor or manufacturer for assistance in resolving software-related issues.

8. **Patient-related Challenges:**
Description: Patient factors like obesity, respiratory motion, or claustrophobia can pose challenges to image quality.
Troubleshooting:
Patient Instructions: Provide clear instructions to patients regarding breath-holding and remaining still.
Adaptive Techniques: Utilize adaptive imaging techniques to address challenges posed by diverse patient characteristics.

9. **Communication Failures**:
Description: Failures in data transfer or communication between components may disrupt the scanning process.
Troubleshooting:
Check Connectivity: Verify proper connectivity between the CT scanner components.
Network Stability: Ensure network stability and address any issues affecting data transfer.

10. **Quality Assurance Programs:**
Description: Lack of a comprehensive quality assurance program may contribute to ongoing issues.
Troubleshooting:
Establish QA Protocols: Implement regular quality assurance programs, including phantom tests and system checks.
Training: Ensure staff are adequately trained in troubleshooting procedures and preventive maintenance.

## APPLICATIONS: -

**1)Diagnosing causes of pain** - CT imaging can reveal problems in areas like the abdomen, pelvis, spine, head, chest, and extremities by detecting abnormal structures or sources of pain.

**2)Cancer screening and diagnosis** - CT scans are used to detect tumors, determine their location and size, and assess their spread. They are commonly used for cancers of the lung, liver, kidney, and bowel.

**3)Detecting cardiovascular disease** - CT angiography can visualize arteries to check for blockages, aneurysms, and buildup of plaque. Cardiac CT can assess coronary arteries and help diagnose heart conditions.

**4)Neurological disorders** - CT can reveal internal brain abnormalities like tumors, bleeds, strokes, and skull fractures. It is often used in head trauma, stroke, and headache patients.

**5)Guiding medical procedures** - CT is used to guide biopsies, radiation therapy, and minimally invasive surgery procedures by providing visualizations of the patient's anatomy.

**6)Bone imaging** - CT excellently depicts fractures, orthopedic injuries, osteoarthritis, and bone tumors. 3D reconstructions clearly show complex fractures.

**7)Dental/sinus imaging** - CT captures fine details of teeth and jaws. It is commonly used to assess dental implant sites and examine sinus anatomy.

**8)Emergency medicine** - CT scanners are standard equipment in most emergency rooms, allowing rapid diagnosis of trauma, abdominal pain, and other conditions.

## FUTURE SCOPE:-

The future of Computed Tomography (CT) holds significant promise as technological advancements continue to drive innovation in medical imaging. Here's a detailed exploration of the future scope of CT:

**1. Spectral CT:**

Description: Spectral CT captures information about the energy spectrum of X-rays, allowing for improved tissue characterization.
Advancements: Enhanced tissue contrast, differentiation of materials, and potential applications in areas like oncology for improved diagnosis.

**2. Artificial Intelligence (AI) Integration:**

Description: AI algorithms are increasingly being integrated into CT imaging for tasks such as image reconstruction, segmentation, and automated diagnosis.

Advancements: Accelerated image analysis, improved detection of abnormalities, and more personalized treatment plans.

**3. Low-Dose Imaging Techniques:**

Description: Ongoing efforts to minimize radiation exposure through dose reduction strategies. Advancements: Continued development of iterative reconstruction algorithms, adaptive statistical iterative reconstruction (ASIR), and other technologies to maintain image quality at lower radiation doses.

**4. Functional Imaging:**

Description: Combining anatomical and functional information in a single scan to provide a more comprehensive assessment. Advancements: Improved assessment of tissue perfusion, oxygenation, and metabolic activity for better understanding of disease processes.

**5. Dynamic Imaging:**

Description: Real-time or dynamic imaging capabilities for capturing changes in organ function and blood flow over time. Advancements: Applications in cardiovascular imaging, musculoskeletal studies, and dynamic assessment of organs during various physiological processes.

**6. Portable and Compact CT Scanners:**

Description: The development of smaller, portable CT scanners for point-of-care imaging.

Advancements: Increased accessibility in remote or emergency settings, quicker diagnostics, and potential applications in field medicine.

**7. Advanced Contrast Agents:**

Description: Continued research into novel contrast agents for better tissue differentiation. Advancements: Improved visualization of specific structures, enhanced diagnostic capabilities, and reduced potential side effects.

**8. Multi-Modal Imaging Integration:**

Description: Integration of CT with other imaging modalities like positron emission tomography (PET) and magnetic resonance imaging (MRI). Advancements: Comprehensive assessment of both anatomical and functional aspects in a single imaging session, providing more comprehensive diagnostic information.

**9. Automated Workflow and Reporting:**

Description: Automation of image processing, analysis, and reporting through advanced software solutions. Advancements: Increased efficiency in the interpretation of images, standardized reporting, and streamlined workflow for healthcare professionals.

**10. Point-of-Care Applications:**

Description: Expansion of CT applications beyond traditional radiology departments to various clinical settings. Advancements: Bedside imaging, emergency room applications, and quick assessments for immediate clinical decision-making.

**11. 3D Printing and Virtual Reality:**

Description: Integration of CT data into 3D printing and virtual reality applications for surgical planning and medical education. Advancements: Personalized surgical models, improved preoperative planning, and enhanced training opportunities for healthcare professionals.

**12. Continued Research in Oncology:**

Description: Ongoing research to refine CT's role in oncology, including early cancer detection and monitoring treatment response. Advancements: Improved sensitivity and specificity for early cancer detection, assessment of tumor microenvironment, and evaluation of treatment efficacy.

## FEATURES OF ELECTROLYTE ANALYZER:-

Computed Tomography (CT) scanners have evolved significantly over the years, incorporating advanced features that enhance diagnostic capabilities and patient care. Here's a detailed exploration of key features found in modern CT systems:

**1. Multi-Slice Capability:**

Description: Modern CT scanners can acquire multiple slices simultaneously during a single rotation.

Advantages: Faster scanning times, improved spatial resolution, and enhanced imaging of moving structures.

**2. Spiral or Helical Scanning:**

Description: The scanner continuously rotates while the patient table moves, allowing for volume data acquisition.

Advantages: Enables faster image acquisition, reduced motion artifacts, and improved three-dimensional visualization.

**3. Dual-Energy CT:**

Description: Utilizes two different X-ray energy levels to differentiate materials based on their atomic composition.

Advantages: Improved tissue characterization, enhanced visualization of contrast media, and reduced beam-hardening artifacts.

**4. Cone-Beam CT:**

Description: Employs a cone-shaped X-ray beam, beneficial in specific applications such as dental and interventional imaging.

Advantages: Reduced radiation dose, improved spatial resolution, and enhanced visualization of anatomical structures.

**5. Low-Dose Techniques:**

Description: Various dose reduction strategies, including iterative reconstruction algorithms and automatic exposure control.

Advantages: Minimizes radiation exposure while maintaining image quality, suitable for pediatric and routine imaging.

**6. Cardiac Gating:**

Description: Synchronizes image acquisition with the cardiac cycle to minimize motion artifacts in cardiac imaging.

Advantages: Improved visualization of coronary arteries, precise assessment of cardiac function, and reduced motion-related blurring.

**7. Perfusion Imaging:**

Description: Evaluates tissue perfusion by assessing contrast enhancement over time.

Advantages: Enhanced assessment of organ function, particularly in oncology and neuroimaging.

**8. Metal Artifact Reduction:**

Description: Algorithms and techniques to minimize image artifacts caused by metal implants or prosthetics.

Advantages: Improved image quality in the presence of metal, allowing for better assessment of surrounding tissues.

**9. 3D and 4D Imaging:**

Description: Reconstruction techniques that allow for three-dimensional and four-dimensional visualization of anatomical structures.

Advantages: Enhanced spatial understanding, improved preoperative planning, and dynamic assessment of moving structures.

**10. Advanced Reconstruction Algorithms:**

Description: Iterative reconstruction methods that improve image quality and reduce noise.

Advantages: Higher image quality at lower radiation doses, improved diagnostic accuracy, and enhanced visualization of subtle structures.

**11. Virtual Colonoscopy:**

Description: Non-invasive imaging technique for assessing the colon using 3D CT images.

Advantages: Reduced invasiveness, improved patient comfort, and potential for early detection of colorectal abnormalities.

**12. Automated Workflow and Post-Processing:**

Description: Streamlined workflow through automated processes for image reconstruction, analysis, and reporting.

Advantages: Increased efficiency, standardized reporting, and improved overall productivity.

**13. Wide-Bore and Open Designs:**

Description: CT scanners with larger gantry apertures to accommodate patients with claustrophobia or larger body sizes.

Advantages: Improved patient comfort, enhanced accessibility, and reduced anxiety during imaging.

**14. Adaptive Image Filters:**

Description: Image processing filters that adapt to the specific clinical task, improving image quality.

Advantages: Optimized visualization of different anatomical structures, providing flexibility in imaging protocols.

**15. Artificial Intelligence Integration:**

Description: Integration of AI algorithms for tasks such as image reconstruction, segmentation, and automated analysis.

Advantages: Accelerated image processing, improved detection of abnormalities, and enhanced diagnostic accuracy.

**16. Dose Monitoring and Reporting:**

Description: Systems equipped with tools for monitoring and reporting radiation doses.

Advantages: Ensures adherence to ALARA (As Low As Reasonably Achievable) principles, optimizing patient safety.

Modern CT scanners offer a plethora of features that contribute to their versatility, diagnostic accuracy, and patient-centered imaging. As technology continues to advance, these features will likely evolve, further enhancing the capabilities of CT in various clinical scenarios.

## CONCLUSION:-

Computed Tomography (CT) stands at the forefront of medical innovation, seamlessly integrating X-ray technology with computational advancements. CT scanners have evolved into indispensable instruments, offering clinicians unparalleled insights into the complexities of the human body. With features like multi-slice capability, dual-energy imaging, and the incorporation of artificial intelligence, CT is poised for a future characterized by heightened diagnostic precision and tailored patient care. Its applications span diverse medical fields, from oncology to cardiovascular imaging, providing detailed cross-sectional images crucial for accurate diagnoses and treatment strategies. Anticipating continued advancements, Computed Tomography remains on an unwavering trajectory of innovation, ensuring its pivotal role in medical imaging and contributing to elevated standards in patient outcomes and medical knowledge.

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