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**QUICK POINTS**

- Biomedical support persons that work on imaging equipment for manufacturers are often referred to as Field Support Engineers or FSE.
- A computed tomography or CT scanner is a non-invasive diagnostic imaging device that produces virtual axial slices of the body the user views by scrolling through them on a display.
- The axial images can be reformatted into two other planes, coronal and sagittal images and into 3D volume rendered images.
- CT radiation dose is always an issue as too much radiation dose is linked to causing cancer.
- A CT scanner processes small volumes of area within the body called voxels. Each organ can be divided into millions of voxels. Each voxel has a number that corresponds to the amount of attenuation of x-rays passing through it. These numbers are referred to as Hounsfield units or HU. Water has a HU value of 0 and air has a HU value of -1000.
- The higher the HU number, the whiter the tissue appears. Air has a HU value of -1000 which appears black compared to cancellous bone with a HU value between +700 to +3000 which appears white in CT images.
- Unfortunately, soft tissue’s HU range is small, between about 20 to 70 HU, making soft tissue detail difficult in CT images.
- The human eye can only see a finite number of shades of gray between black and white. The user
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adjusts the window and level values to adjust how the tissue(s) appear on a monitor. Some adjustments will emphasize specific tissue.

- CTs have five generations of design, the third generation being the most common in use which uses slip-ring technology and a rotational x-ray tube and detectors.
- CT image quality can be defined by comparing the actual object to the CT scanned image produced of the object.
- CT image quality is monitored using phantoms to measure spatial resolution, contrast resolution, noise and uniformity tests.
- Servicing a CT requires about 4 – 8 weeks of manufacturer training which is specific training on the manufacture’s specific CT.
- Specific to the CT, the biomedical Field Support Engineer verifies slice thickness accuracy, slice positioning accuracy, image quality, image display check, performs specific preventative maintenance and performs diagnostic tests.
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**CHALLENGE QUESTIONS**

1. What is a CT scanner used for?
2. What other types of image formats are available besides axial images?
3. What is CT raw data?
4. What are Hounsfield Units?
5. Why is CT radiation dose an issue?
6. How does air or bone appear in a CT image?
7. How does x-ray and CT images differ?
8. How is contrast resolution measured?
9. How is spatial resolution measured?
10. If the HU number of a water phantom vary by more than 2, how would this be interpreted?
11. What are the components of a gantry?
12. When the CT technologist increases the tube current, what happens?
13. Why would the CT technologist increase tube kV?
14. What happens if a CT technologist adjusts the pitch to greater than one?
15. What does post processing mean?
16. What is the difference between reconstruction and reformatting?
17. How is CT Image quality monitored?
18. Why is soft tissue difficult to image?
19. What are the major generation of CTs scanners developed and what is the most common generation in use today?
20. How are ring artifacts fixed?
21. Outline the specific tests a biomed performs on the CT during a PM.
What is a CT scanner and what type of images can it produce?

A computed tomography or CT scanner is a non-invasive diagnostic imaging device that uses multiple X-ray projections (raw data) and lots of reconstruction (post-processing of this raw data) to produce virtual axial slices of the body. These virtual axial slices are reconstructed as the CT scanner moves its table and patient, typically from head to foot, through the gantry’s bore (or opening).
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The user views the virtual axial slices by scrolling through them and viewing them on a computer display. CT images can display any part of the body including bones, muscles, fat, organs, and blood vessels which are much more detailed than standard X-ray images. These axial images can be reformatted into two other planes, coronal and sagittal. Reformatting axial images into other planes is referred to as multiplanar reconstruction or MPR. The user can scroll through consecutive multiple thin axial, coronal and/or sagittal images together to view multiple planes of the same body area.
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CT axial images can also be reformatted into maximum intensity projections or MIP images, also referred to as 3D MIP images. MIP images use two or more axial images reformatted together representing a volume or slab of interest. These images allow a user to see dense structures, in some cases, better than scrolling through the thin axial slices individually. The slab thickness can be changed to help visualize the pathology better, when compared to scrolling through thin axial slices. The MIP reconstructed images can also be created from the other 2 thin slice planes, sagittal and coronal.

CT axial images can also be reformatted into minimum intensity projections or MinIP images, also referred to as 3D MinIP images. MinIP images use two or more axial images reformatted together representing a volume or slab of interest. These images allow a user to see low-density structures, in some cases, better than scrolling through the thin axial slices individually. The slab thickness can be changed to help visualize the pathology better, when compared to scrolling through thin axial slices. The MinIP reconstructed images can also be created from the other 2 thin slice planes, sagittal and coronal.
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CT axial images can also be reformatted into 3D volume rendered images (VR). VR is an algorithm that defines the opacity and color of each voxel based upon the voxels density. The rendering software can then display numerous 3D reconstructed images which can show or hide specific body parts. These 3D rendered images can show bone detail (dense tissue) after removing soft tissue. 3D rendered images can also be used to show vessels, after removing the tissue and bone around them. VR imaging has many uses for displaying numerous body parts as required by the user. There are CT workstations that are specifically designed to reprocess the CT thin slice axial images into VR imaging.
CT imaging can be used to visualize nearly all parts of the body. They can aid with planning medical, surgical or radiation treatment. CT scans are commonly used to see/diagnose many forms of cancers including liver, lung and pancreatic. CT images are used to see/diagnose spinal problems and other bone issues of the body and are commonly used to see/diagnose injuries to internal organs that result from trauma.

What can CT images of the head can show?

- bleeding caused by a ruptured or leaking aneurysm.
- blood clots or bleeding within the brain.
- brain tumors.
- bone and soft tissue damage due to facial trauma.
- images to aid in planning radiation therapy brain cancer.
- images to aid in guiding a needle to obtain a tissue sample or biopsy of the brain.
- images displaying blood vessels.
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What can CT images of the chest can show or identify?
- lung infections and diseases.
- malignant or benign lung tumors.
- pulmonary embolisms or pulmonary aneurysms.

What can CT images of the abdomen/pelvis show or identify?
- injuries to the spleen, liver, kidneys.
- kidney or bladder stones.
- infections, intestinal obstruction or bowel diseases.
- cancers: liver, kidneys, pancreas, ovaries or bladder.
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*Are there options to reprocessing of RAW data?*

It is not uncommon for the original CT RAW data to be reprocessed using different algorithms to improve specific tissue image detail. An example can be reprocessing the RAW data using a bone algorithm which improves bone detail of the axial images but sacrifices soft tissue detail. Other reprocessing algorithms are used to reprocess soft tissues to improve soft tissue detail sacrificing bone detail.

*How do X-ray and CT imaging differ?*

X-ray images show hard tissue information in a 2D format. An x-ray image may show a skull fracture but can’t show the location or extent of the fracture as it is a 2D image. CT imaging can show hard and soft tissue information in a 3D format. An CT images can show a skull fracture’s location and the extent of the fracture, via the additional 3D imaging information.

A conventional x-ray image uses a very low dose of radiation when compared to CT imaging that requires a much higher dose of radiation.

*What are the risks of a CT scan?*

CT radiation dose is always an issue. CT manufacturers and users are always trying to maintain image quality while reducing dose. To much radiation dose is linked to causing cancer. One average head CT gives a radiation dose that would naturally occur in about 243 days. One average abdomen CT gives a radiation dose that would naturally occur in about 2.7 years. CT users try to obtain the image quality required with the lowest possible dose. Image quality and radiation dose delivered to the patient are related.
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CT TECHNOLOGY INFORMATION

How are CT images produced?

X-ray imaging is a 2-D image and can’t distinguish organs behind or in front of a bone. CT imaging uses x-rays and produces 3-D imaging by rotating an x-ray tube around the patient. On the opposite side of the x-ray tube are x-ray detectors. The x-rays pass through the patient as it is rotated around the patient. The detectors opposite the x-ray tube detect the number of x-rays that pass through the patient (not absorbed by the patient). These x-rays are then processed by the CT scanner to produce 3D axial images, hence the term computed topography.

A CT scanner’s processor system calculates small volumes of area within the body called voxels. Each organ can be divided into millions of voxels. Each voxel is represented by a number that corresponds to the amount of attenuation or absorption of the x-rays passing through it. These numbers are referred to as Hounsfield units or HU. Bone has a very high HU number because the absorption (attenuation) of x-rays passing through bone is very high. Bone in CT images are displayed as white. Skin will have a very low HU number because skin has a low absorption of x-rays as most x-rays pass through skin. Air has no attenuation of x-rays and is displayed as black in CT images. As the HU numbers or density of the tissue increases, the color of that tissue becomes lighter. In summary, air which is the least dense tissue is black, as tissue density increase the color turns from dark grey to lighter shades of gray until the densest tissue, bone which is white. Air has a HU value of -1000, water has a HU value of 0 and teeth have a HU value ranging from about 500 to 2000.
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Each individual projection of x-rays pass through numerous tissues with numerous voxels in its path. With each individual projection, a HU value is calculated which is a sum of all these voxel values (HU) added together. As the x-ray tube circles the patient, each angle of the x-ray projection produces another additive HU number. As the tube rotates around the patient, the CT processes all these additive HU numbers at each different angle. The CT processing can then calculate each individual voxel HU number using the data from all individual projections of each individual voxel.

What are Hounsfield numbers?

CT attenuation values are based upon a linear density scale called the Hounsfield scale (HU), invented by Sir Godfrey Newbold Hounsfield. Water was assigned a value of 0 HU and air has a radiodensity of -1000 HU. A HU value for each pixel is converted into a digital image by assigning a gray-scale intensity to each pixel. A pixel is the smallest element of an image that can be individually processed in a video display. The higher the HU number, the brighter the pixel intensity. Using the Hounsfield scale, air has a value of −1000 which appears as black in CT images. Cancellous bone has a HU value of between +700 (cancellous bone) to +3000 (dense bone). Since bones are dense, they appear as very close to white in CT images. Fat is less dense than water, with a HU value between −30 to −70. Fat always appears darker (shades of grey) when compared to water in CT images. Unfortunately, soft tissues and organs have close Hounsfield values and are therefore more difficult to see when they are adjacent to each other. Often contrast agents are used to make some structures
standout in CT images, such as the blood vessels. The contrast when flowing through structures will change its HU number making it easier to see in CT imaging. A difference of 10 HU is about a 1% contrast difference.

How does adjusting the window and level change viewing the images?

The human eye can only see a finite number of shades of gray between black and white. Adjusting the window and level numbers will adjust how the tissue(s) is displayed on a monitor. Using the HU scale, if the level is zero and the window is 2000, all the viewable shades of grey are distributed evenly starting with black at the HU number of 1000 and white at the HU number of -1000. All HU numbers between this will be progressive shades of grey. Unfortunately, soft tissue varies between about 20 to 70 HU and using this window and level would not have enough shades of grey in this range to properly display details of these soft tissues. If the user sets the level to about 40 with a window of 80, this would set all the visible shades of grey to...
display much more detail of soft tissue. This would however make all tissue with HU values above 80 black and all tissue with values below 0 white. When viewing CT imaging, the user adjusts the window and level to maximize the viewable shades of grey of the tissue HU range they are viewing, to obtain this tissue details.

What are the major parts of CT scanner: 3rd generation

Gantry:
- **X-ray tube/generator**: a system that generates x-rays and includes a vacuum tube that converts electrical input power to x-ray radiation. The generator produces a high voltage.
- **Cooling system**: used to reduce the heat generated during scanning, mainly of the x-ray tube.
- **Collimator**: it is located between the filter and patient to control beam width or slice thickness, reduces x-ray scatter and lowers patient dose.
- **X-Ray Detectors**: solid state detectors that convert x-rays into light photons. The CT detectors measure attenuation or absorption of x-rays by the patient’s tissue.
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- **Data acquisition system (DAS):** the DAS measures the photons that pass through the patient and strike the x-ray detectors. It then converts the analog light signal from the detector into a digital signal.
- **Laser lights:** used to position the patient at a specific spot and align the patient horizontally.
- **Slip-ring system:** it enables continuous rotation of the gantry frame allowing helical scanning.

**Patient table:**
- Moves the patient through the gantry hole with precision, as the x-ray tube spins around them.
- The gantry laser lights are used to position the patient on the table properly prior to starting a scan.

**Operator console:**
- **Acquisition setup:** allows the CT technologist to configure all the parameters used to acquire images, usually based upon body part scanned.
- **RAW-processing:** computers and/or hardware that process the RAW data from the gantry and converts this RAW data into axial images.
- **Post-processing:** computers and/or hardware that reformats to axial images into other image formats such as coronal and sagittal planes, etc.

**Post-processing computer:**
- Manufacturers often include a separate post-processing computer which removes this task from the operator console.
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- This post-processing computer allows the user to scan the next patient quicker, eliminating the need to post-process images on the operator console.

**How have CT scanners evolved?**

The first CT scanners were used in 1971 and had a single detector. Sir Godfrey Hounsfield used it for brain studies only. The first two generation of CT scanners were slow and image quality was limited. The tube could not rotate around the patient and processing RAW data was slow. Third generation CTs greatly improved speed and image quality with numerous iterations. The tube could now rotate around the patient continuously using slip rings, processing continually became faster and image quality greatly improved. This is the most common CT generation in use today. The fourth generation CT scanner is like a third-generation scanner although the detectors are stationary and has a faster scanning time. The fifth-generation scanner has the fastest image processing ability, has no moving parts in the gantry and is mainly used for cardiac scanning.
CT IMAGE QUALITY

How can CT image quality be defined?
CT image quality can be defined by comparing the actual object scanned to the CT scanned image produced of the object. The more details of the CT scanned object image, when compared to the actual image, the better the quality of the scanned image.

What limits image quality?
Image quality starts at the detectors. The detector’s image quality is the best the CT scanner can display, using specific scan parameters. The processing after the CT detectors which include the DAS, image processing and display system, can either display this detector image quality or change the image quality to alter how it is displayed. Software can however enhance the image to optimize image quality and decrease blur, improve bone sharpness, etc.

How is CT image quality measured?
Two common measurements used to determine image quality of CT images are spatial resolution and contrast resolution. Other tests include image noise and uniformity tests. Image quality tests are usually run monthly or quarterly. Some tests are run daily or weekly, dependent upon the CT scanner. Most manufacturers have a specific software routine that scans a specific phantom and performs automated calculations of image quality which includes the spatial resolution, contrast resolution, noise and uniformity tests.
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What is spatial resolution?

Spatial resolution is the ability to distinguish between small, high contrast objects without blurring of the images. A high spatial resolution is required to discriminate between objects that are close to each other. Spatial resolution may also be referred to as detail resolution, the sharpness of an image, detail resolution, Modular Transfer Function (MTF) or the high-contrast spatial resolution. Spatial resolution measured by using a line pair phantom, scanning the phantom and the counting visible strips. Spatial resolution is affected by noise and is dependent upon many factors including the detectors, slice thickness, display FOV, pixel matrix, focal spot, imaging technique used to acquire the images and the algorithm used to process the acquired RAW data. Manufacturers often describe spatial resolution in line pairs per centimeter (lp/cm). The detail specifications are only comparable between different CTs if the images were acquired the same using the same or similar scanning parameters, etc.
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What is contrast Resolution?
Contrast resolution of CT scanners is the ability to resolve tissue from its surroundings, when the HU numbers are similar. A good contrast resolution is required to discriminate between subtle differences in tissue. Contrast resolution is measured by using phantoms that contain objects of varying sizes and with a small difference in density compared to the background. Contrast resolution is affected by noise and is dependent upon many factors including the detectors, slice thickness, imaging technique used to acquire the images and the algorithm used to process the acquired RAW data. Manufacturers often describe contrast resolution in millimeters (mm). The contrast resolution specifications are only comparable between different CTs if the images were acquired the same using the same or similar scanning parameters, etc.
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How is image noise and uniformity tested?

Noise in CT images can be described as grainy images or an image with a salt-pepper image. Noise affects spatial and contrast resolution and manufacturer’s try to limit this noise to improve the spatial and contrast resolutions.

The noise uniformity test uses a water phantom. The water’s CT number is zero and the air surrounding the phantom is -1000. The phantom is scanned at specific slice thicknesses and tube settings. Region of Interest (ROI) is measured in the center of the phantom (water) and a few at the peripheral to measure field uniformity which should not vary by more than about +/-5HU. ROI is also measured outside the phantom (air) and should measure about -1000 HU, +/-5 HU. Most manufacturers have a specific software routine that scans the water phantom and performs and calculates the image noise and uniformity. This test is usually run daily or weekly by the operator.
What are CT image artifacts?

Image artifacts are anything in a CT image which is not present, in the actual object scanned. *Streak artifacts* are usually caused by materials that block X-rays, such as metal or bone. *Partial volume effect artifact* appears as a blurring of edges usually due to the CT scanner not able to differentiate between a small amount of high-density tissue and a larger amount of lower density tissue. *Ring artifacts* are usually due to one or more detector defects or miscalibration and appear as bright or dark rings in a 3rd generation scanner. Recalibrating the detectors usually fixes ring artifacts or the faulty detector(s) are replaced. *Noise artifacts* appear as grain or lines on the image and is usually caused by a low signal to noise ratio, more visible in thin slices. *Motion artifacts* are caused by patient movement while acquiring images, including breathing during some scans. Motion artifacts can appear as blurred, double images or even streaks within the images.
What is an image display check?

The display system of the CT modality must be checked to ensure it can display the CT images and not degrade the images. This is usually checked by using a SMPTE pattern. This pattern allows the FSE to check the display system using varying shades of grey between black (0%) and white (100%) varying in shades of grey by 10% increments. It is important to ensure the white and 95% shade and the 5% and black can be seen next to each other.
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**CT SCANNER SCANNING PARAMETERS**

The most common CT scanners in use today are 3rd generation, helical, multi-slice scanners. Some of the parameters below are based upon these scanners. CT parameters selected are based upon the clinical imaging needs and are usually set within protocols. Protocols define the clinical image. The CT technologist can often change many parameters if required, after selecting a protocol.

**Tube Current (mA):**
- Tube current is measured in milliamperes (mA) and represents the number of electrons flowing through the cathode filament. Radiation dose is directly proportional to mA.
- mAs is the product of tube current and exposure time.
- Increasing the tube current (mA) improves image quality and reduces noise.
- Increasing the tube current (mA) also increases radiation dose.

**Tube Voltage (kVp):**
- The tube voltage, measured in kilovoltage peak (kVp), is measured between the cathode and anode of the x-ray tube.
- Increasing the tube voltage improves contrast resolution, improving the ability to distinguish between similar tissue densities (HU).
- Increasing the tube voltage also increases radiation dose.
- The CT technologist may increase tube voltage on larger patients to get better penetration and image
quality (less noise). The tube voltage for a routine CT adult body is typically between 120 to 140 kVp.

Field of View (FOV):
- There are two field of views when it comes to CT scanners, the *scan field of view* (SFOV) and *display field of view* (DFOV).
- The scan field of view (SFOV), also referred to as the acquisition field of view, is the area within the gantry that RAW data is acquired.
- The display view of field (DFOV), also referred to as the reconstructed field of view, is the portion of the RAW data that is reconstructed. It can be all the RAW data (SFOV) or less.

Slice thickness Parameter:
- The scan parameters or user prior to scanning set the slice thickness. The CT system uses the collimator to adjust the slice thickness.

Pixel size:
- A pixel is a smallest unit of a digital image that can be displayed on a monitor.
- Matrix size defines how many pixels are present. CT matrix sizes include 256x256, 512x512 and 1024x1024.
- The best detail of an image can be achieved by a small FOV, large matrix size and thin slices.
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Pitch Parameter:

- Pitch is the area of raw data acquired during one complete rotation of the x-ray tube (360°).
- If the table of a single slice CT scanner moves 5 mm in one rotation and the slice thickness (or beam collimation) is 5 mm, the pitch is 5 mm / 5 mm = 1.
- If the table of a multislice CT scanner moves 50 mm in one rotation and the total slice thickness of all slices is 50 mm, the pitch is 50 mm / 50 mm = 1.
- When the pitch is 1, the x-ray raw data is contiguous.
- When the pitch is greater than 1, the x-ray raw data is not contiguous and there are gaps in the x-ray raw data as some tissue is not scanned. A pitch greater than 1 results in decreased patient dose but also decreased image quality.
- When the pitch is less than 1, the x-ray raw data is not contiguous and there are overlaps in the x-ray raw data as some tissue is scanned more than once. A pitch less than 1 results in better image quality, but a higher patient dose.
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Reconstruction or RAW data:
- The RAW data after acquired must processed and the user can select how it is reprocessed based upon why the imaging was acquired.
- If the user is looking for bone detailed imaging, they would reconstruct the RAW data using a bone algorithm or filter. This filter emphasizes bone detail but reduces the visibility of soft tissue.
- To obtain greater detail or special resolution, detail algorithms sacrifice low contrast resolution.
- To obtain greater contrast resolution, smoothing algorithms sacrifice spatial resolution.
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**CT SETUP: Acquiring the images**

1. The CT technologist admits the patient on the CT scanner via:
   a. manually entering the patient information.
   OR
   b. selecting the patient from a list on the CT scanner obtained electronically, via other hospital systems.
2. The patient lays on the table and the CT technologist adjusts the location of the patient using laser lights.
3. The CT technologist selects a protocol which pre-defines scanning parameters for the specific anatomical area being scanned.
4. A localizer image is acquired. The CT technologist may modify the scan parameters for acquiring the localizer image. The localizer image can be an AP view (x-ray tube above the patient) or a lateral view (x-ray tube at the side of the patient). Depending upon the CT manufacturer, this localizer image may be referred to as the *scout, surview, scanogram* or *topogram* image.
5. The CT technologist then adjusts the area of the patient to be scanned using the scout image to ensure the scanning covers the area required and is centered to the area being scanned. This is usually done using grid lines over the scout image and adjusting the imaging start and end points (head to foot axis) plus the FOV (right to left axis). The dose value is usually available to view prior to scanning and the user may make parameter changes to reduce this dosage, if possible. Other scanning parameters may also be
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adjusted such as the scan type (axial/helical), rotation time (time the tube takes to rotate 360 degrees), kV, mA, etc.

6. The CT technologist initiates the scan usually by a button at the operator console. Within the gantry, the patient can hear either manual voice information from the user or automated voice prompts letting the patient know the scan is about to begin.

7. The CT technologist reviews the scanned images on the CT scanner display to ensure the images are acceptable. The user may add additional scanning if required. When all imaging is completed, the user ends the exam on the CT scanner.

8. The CT technologist transfers the study to an external post-processing CT workstation and/or PACS system.
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HOW TO TEST/PM THE CT

SERVICE NOTES: Servicing a CT requires manufacturer training. This is usually between 4 – 8 weeks. It includes specific CT training on the manufacture’s specific CT model. Even an experienced CT imaging tech (or field service engineer) who works for the manufacturer, gets trained on the new CT models, prior to servicing it. Each CT model requires specific training on hardware and service application. Always refer to the manufacturer's service manual for a complete recommended PM guideline. Following is a generic guideline only!

Perform a visual inspection:
- The biomed checks the overall CT scanner looking for obvious issues such as a table issues, console issues, etc.

Ensure all user controls are operational:
- The biomed checks all the user controls are functioning during your tests.
  - A biomed will often find user controls not working during their testing. If a button/control is not working, repair it prior to placing the CT scanner back into service, if possible.

Ensure the date and time are accurate:
- It is very important all systems including CT scanners are at the same time to correlate patient
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imaging and treatment. Correct the date/time if required.

Review error logs:
- Always check the error logs accumulated by the CT scanner during use, if available.
- CT error logs are usually available in-service mode. These logs are very helpfully and may include basic to very detailed information. Often these logs will show detector issues, tube arc, etc and often show operational issues the user may be unaware of during use.
- These error logs are also useful when the CT fails and may be useful to quickly point to the failed system(s).

Verify slice thickness accuracy:
- The manufacturer will have specific routines that checks and/or calibrates slice thickness accuracy.
- This test or calibration is performed on a routine basis.

Verify slice positioning accuracy:
- The manufacturer will have specific routines that checks and/or calibrates slice positioning accuracy which involves the laser positioning lights and table positioning.
- This test or calibration is performed on a routine basis.
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Verify image quality:

- **Spatial resolution**: the spatial resolution test requires a phantom. Spatial resolution is measured by using a line pair phantom, scanning the phantom and the counting visible strips. Most manufacturers have a specific software routine that scans the spatial resolution phantom and calculates the spatial resolution in line pairs per centimeter (lp/cm).

- **Contrast resolution**: Contrast resolution is measured by using a contrast phantom. Most manufacturers have a specific software routine that scans the contrast phantom and measures the small difference in the object(s) density and compares it to the background, to calculate density accuracy.

- **Image noise and uniformity**: The noise uniformity test uses a water phantom. The water’s CT number is zero and the air surrounding the phantom is -1000. Noise is measured by measuring a water phantom and computing a mean and standard deviation by use of an ROI. When checking uniformity, the ROI HU values in general should not differ by more than about 5 HU of water or air, but this number is set by the manufacturer. Most manufacturers have a specific software routine that scans the water phantom and performs and calculates the image noise and uniformity.

- **Verify image display system quality**: Tests the display system typically using a SMPTE pattern.

- The manufacturer will outline other image quality scans that are specific to the CT.
Perform preventative maintenance:

- **Slip rings**: The slip rings allow the moving section of the gantry to continuously spin around the patient. The manufacturer will have a specific routine and method of maintaining the slip rings. This may include cleaning and/or replacement of brushes.

- **Patient Table**: The patient table moves the patient through the gantry opening precisely. The manufacturer will have a specific routine and method of maintaining the table that may include cleaning, lubrication, and calibrations.

- **DB maintenance**: All patient data is stored on the system. The manufacturer may have database checks, cleanup, and maintenance to ensure the integrity of this DB.

- **X-ray tube**: Some tubes require periodic maintenance and calibration checks. The CT system service mode usually includes routines that are designed to check and/or calibrate the tube during a PM.

- **Cooling system**: The x-ray tube is very expensive and can last a long time if maintained properly and kept cool during use, by the cooling system. The manufacturer will have a cooling system check and/or maintenance routine to ensure the cooling system is working as designed.

- **Room temperature**: The FSE must ensure the room temperature and humidity is maintained specific levels to ensure CT operation. High temperatures and/or humidity can lead to image quality issues and even CT system failures.
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- **Dust**: large amounts of air is constantly flowing through a CT gantry and console picking up dust. Manufacturers require regular cleaning of fans, filters and vacuuming dust out of cabinets and consoles regularly. Dust build-up can impede air flow which increase internal temperatures and cause part failures and/or system shutdowns due to high temperatures.

- **Detector calibration**: on a schedule, the manufacturer may require a full calibration of the detectors or if specific image quality checks fail. The manufacturer will outline a detector calibration routine and guide for calibration of the detectors.

**Perform diagnostic tests:**

- The manufacturer usually has a routine of diagnostic tests that are run during PM. These routines check for proper operation of major CT systems looking for any issues with them. These same routines are sometimes used during a CT scanner failure.

- These tests are performed on a routine basis.

**Always perform a final functional check:**

- As a final test, the biomed should do a quick CT functional test to ensure proper operation, prior to placing it back into service.

- All operation, controls and alarms should operate as per the manufacturer's design.
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Ensure your documentation is accurate:
- All repairs and performance tests need to be documented so that they can be retrieved at any time.
- This documentation should include all parts used for repair and that all the above tests showing the equipment is within manufacturers' and local authorities acceptable limits.
- These documents may be used legally to validate the proper maintenance was performed by the biomed or FSE. Ensure the documentation is accurate!

What do I do if any of my checks fail?
- If any imaging device fails QA image tests, or functional test, it is the biomed’s or FSE’s responsibility to fix the issue(s) prior to allowing the CT scanner to image a patient again!
- Failure means imaging is not within specifications and misdiagnosis using these images may occur!
- Fix the issues prior to placing the CT scanner back into service!
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**CHALLENGE ANSWERS**

1. A CT scanner is used to produce non-invasive diagnostic virtual axial slices of the body that the user can view by scrolling through on a display.
2. The axial images can be reformatted into two other planes, coronal and sagittal images and into 3D volume rendered images.
3. CT raw data is multiple x-ray projections acquired as the tube is spun around the patient as they move through the bore of the CT scanner.
4. Hounsfield units are a unit of measure that represents the different density levels of tissues and or other substances. The density of pure water is 0 HU and air is -1000 HU.
5. CT radiation dose is always an issue as too much radiation dose is linked to causing cancer.
6. Air appears black compared to bone which appears white in CT images.
7. X-ray imaging is a 2-D image and can’t distinguish organs behind or in front of each other compared to CT images which can.
8. Contrast resolution is measured using phantoms that contain objects of varying sizes and with a small difference in density compared to the background.
9. Spatial resolution measured by using a line pair phantom, scanning the phantom and the counting visible strips.
10. If the HU number of a water phantom vary by more than 2, this would be interpreted as a noisy image since the HU numbers vary by more than 2 HU.
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11. The components of a gantry include the X-ray tube/generator, the Cooling system, the Collimator, the X-Ray Detectors, the DAS, Laser guide lights and the slip-ring system.

12. When the CT technologist increases the tube current, this improves image quality and reduces noise but increases radiation dose.

13. The CT technologist may increase tube voltage on larger patients to get better penetration which improves image quality.

14. If the CT technologist adjusts the pitch to greater than one, the x-ray raw data is not contiguous and there are gaps in the x-ray raw data as some tissue is not scanned. A pitch greater than 1 results in decreased patient dose but also decreased image quality.

15. Post processing means manipulating the raw or images data, after scanning, to change how the images look.

16. Reconstruction is using raw data to produce axial images compared to reformatting which converts axial images into other planes (coronal/sagittal) or produces 3D images.

17. CT image quality is monitored using phantoms to measure spatial resolution, contrast resolution, noise and uniformity tests.

18. Soft tissue is difficult to image using a CT scanner because soft tissue’s HU range is small, between about 20 to 70 HU.

19. CTs have five major generations in design, the third generation being the most common in use which uses slip-ring technology and a rotational x-ray tube and detectors.
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20. Ring artifacts are fixed by recalibrating the detectors or replacing the faulty detector(s).
21. Specific to the CT, the biomedical Field Support Engineer verifies slice thickness accuracy, slice positioning accuracy, image quality, image display check, performs specific preventative maintenance and performs diagnostic tests.