CT image quality

Because CT images are composed of ***discrete pixel values***, image quality is somewhat easier to ***characterize and quantitate***.

A number of methods are available for CT image quality is dependent on:

- Image contrast
- Spatial resolution
- Noise
- Artifacts

Depending on the ***diagnostic task***, these factors ***interact to determine sensitivity***; the ***ability to perceive low and high contrast structures*** to yield a diagnostic CT image and the ***visibility of details***.

Image Contrast

The ability to distinguish one soft tissue from another without regard for size or shape is called contrast resolution. This is an area in which ***multislice helical CT excels***. CT ***image contrast depends on subject contrast and display contrast***. Display contrast is arbitrary and ***based on the windowing parameters*** (window ***level*** and window **width**).

As in radiography, CT subject contrast is determined by ***differential attenuation***: that is, ***differences in X-ray attenuation*** by absorption or scattering in different types of tissue and thus resulting in ***differences in the intensity*** of the X-rays ultimately reaching the detectors. Because of the ***high peak kilovoltage*** and relatively ***high beam filtration*** (beam hardness) used in CT, most of the radiological events in CT are ***Compton scatter events*** which ***differ in intensity*** based on differences in ***tissue electron density*** (electrons/ cm^3), which in turn are due primarily to differences in ***physical density***.

Thus, ***subject soft-tissue contrast*** in CT comes mainly from ***differences in physical density***. That the ***small differences in soft-tissue density*** can be ***visualized on CT*** is due to the nature of the image (a 2-dimensional image of a 2-dimensional slice). However, these differences may be ***mapped to large differences in grey levels*** (grey scale) through ***windowing*** which ***makes CT visualization of various tissues possible***.

<u>For more Explanation:</u>

The ***absorption of X-rays*** in tissue is characterized by the X-ray linear attenuation coefficient. This coefficient, as we have seen, is a ***function of X-ray energy and the atomic number of the tissue***. In CT, absorption of X-rays by the patient is determined also by ***the mass density of the body part***. Consider the situation outlined in Figure (1), a fat–muscle–bone structure. Not only are the atomic numbers somewhat different (Z_{fat} = 6.8, Z_{muscle} = 7.4, and Z_{bone} =13.8), but the mass densities are different (ρ = 0.91, 1.0, and 1.85 g/cm^3, respectively). Although these differences are measurable, ***they are not imaged well on conventional radiography***.

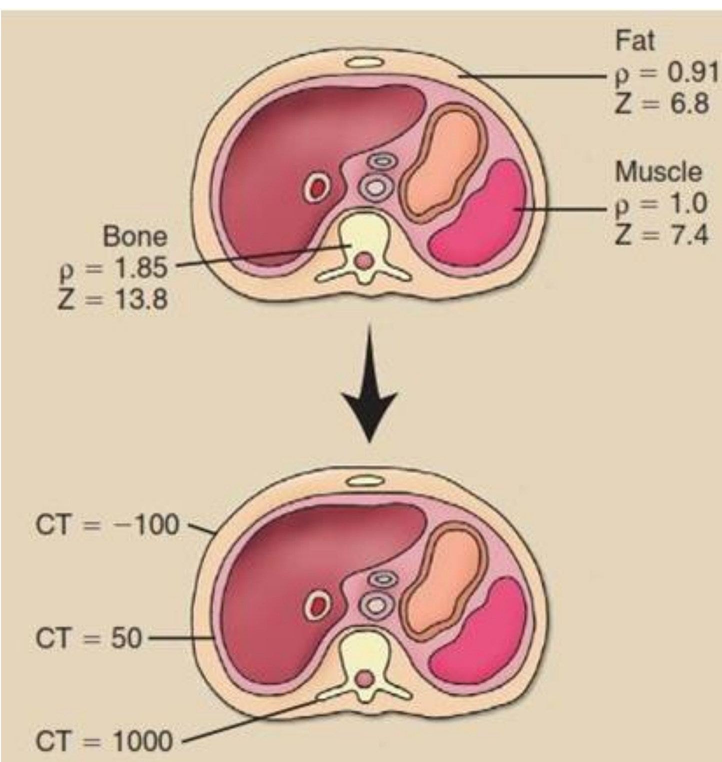

Fig. (1): No large differences are noted in mass density and effective atomic number among tissues, but the differences are greatly amplified by computed tomography imaging.

The CT imaging system is able to ***amplify these differences in subject contrast*** so the image contrast is high. The range of ***CT numbers*** for these tissues is ***approximately −100, 50, and 1000***, respectively. This amplified contrast scale allows CT t***o better resolve adjacent structures that are similar in composition***.

The ***contrast resolution provided by CT is considerably better than that available in radiography*** principally ***because of the scatter radiation rejection of the prepatient and predetector collimators.*** The ability to image ***low-contrast objects*** with CT is ***limited by the size and uniformity of the object*** and ***by the noise of the system***.

<u>Factors influencing contrast:</u>

1) ***Noise:*** a higher noise will obscure any contrast between objects
2) ***Tube current:*** a higher tube current reduces the noise in the image
3) ***Inherent tissue properties:*** the difference in the linear attenuation coefficient of adjacent imaged objects will determine the contrast between those objects
4) ***Beam kilovoltage:*** a higher beam energy will reduce the contrast between objects
5) ***Use of contrast media***

<u>CT Spatial Resolution</u>

Spatial resolution in CT, as in other modalities, is ***the ability to distinguish small, closely spaced objects on an image***.

Characteristics of the CT imaging system that contribute to such image degradation include ***collimation***, ***detector size***, ***mechanical and electrical gantry control***, and the ***reconstruction algorithm***.

Factors affecting spatial resolution

If one images a regular geometric structure that has a ***sharp interface***, the image at the interface will be somewhat ***blurred***. The ***degree of blurring*** is a measure of the spatial resolution of the system and is controlled by a number of factors:

1. Focal spot

Spatial resolution is determined by X-ray tube focal spot size as well as blurring occurring in the image detector. Focal spot size is a contributor to spatial resolution (***smaller focal spot size equals better spatial resolution***).

2. Detectors size

The size of the detector measurements (referred to as ***aperture size and represents sampling size***) and the ***detector spacing*** (spacing of measurements) are the predominant factors that determining a CT scanner's spatial resolution.

The ***smaller the detector measurement capability*** and the ***closer the detector spacing*** is the ***better the spatial resolution***. This concept is known as ***sampling***.

Detectors must be the ***same size or smaller than the imaged object in order to resolve it***. In addition, detectors must be ***close together to resolve objects that are near to each other***. Further, the detectors must be ***properly aligned***. ***Improper alignment*** may result in ***less resolving power*** than would be predicted by detector size and spacing alone.

3. Pixel size

Spatial resolution is a function of pixel size: ***The smaller the pixel size, the better is the spatial resolution***. CT imaging systems allow reconstruction of images after imaging followed by post-processing tasks; this is a powerful way to affect spatial resolution.

4. Voxel size

The displayed spatial resolution may also be affected by the image reconstruction or by ***the voxel size on the computer screen***. For example, it is possible that ***the voxel size on the computer matrix is too large to resolve an object*** that is theoretically resolvable based on the sampling characteristics. This limitation may be overcome by reducing the scanned field of view which will have the effect of ***yielding smaller voxels***. For example, if the matrix size is 512 voxels by 512 voxels and the scanned field of view is a 50 cm diameter, the voxel size will be 50 cm/512 pixels or approximately 0.1 cm by 0.1 cm by 0.1 cm. However, if the scanned field of view is reduced to 25 cm then the resulting voxel size will be 0.5 cm by 0.5 cm by 0.5 cm.

5. Number of projections

Larger number of projections gives finer resolution (up to a point).

6. Detector slice thickness

The above discussion applies mainly to x and y axis spatial resolution. ***Z axis spatial resolution (head to toe) depends on the image thickness*** which in turn depends on the ***length of the individual detector in the z axis***. In addition, z axis resolution depends on the reconstruction interval (***degree of overlap of z axis image slices***)

Overlapping samples: Acquiring the data ***using overlapping slices can improve Z-sensitivity***. This is achieved by using a low spiral pitch e.g. ***pitch <1***.

Thinner slice thicknesses also allow ***better spatial resolution***. Anatomy that ***does not lie totally within a slice thickness may not be resolved***, an artifact called ***partial volume***.