Radiological Equipment Techniques

Computed Tomography

By

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M.Sc. Theoretical Physics

Second Semester

Experimental 5

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Outline

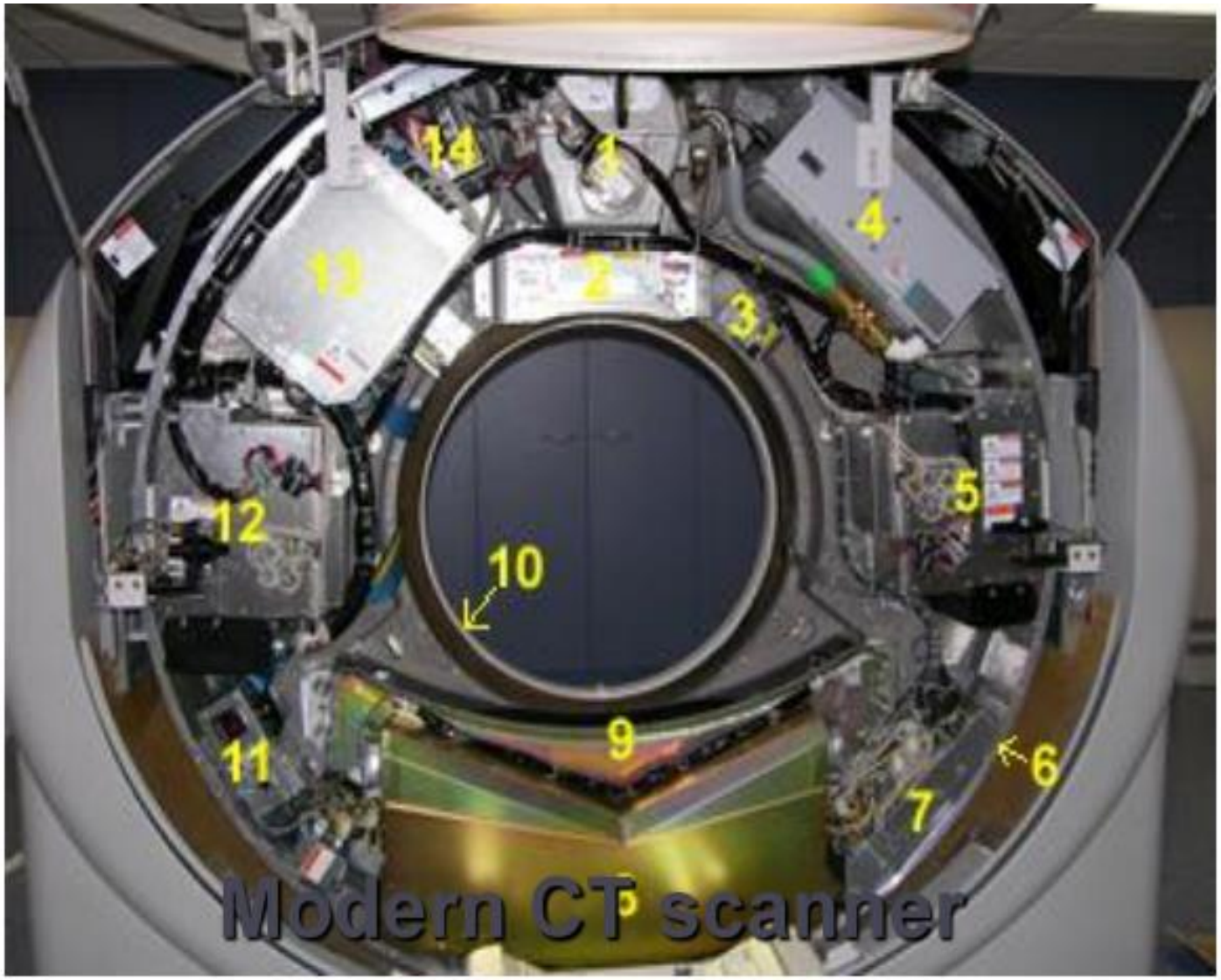
- CT structure
- Operating Steps
- CT Numbers
- Windowing

Modern CT scanner

Label

1. Gantry aperture (720mm diameter)
2. Microphone
3. Sagittal laser alignment light
4. Patient guide lights
5. X-ray exposure indicator light
6. Emergency stop buttons
7. Gantry control panels
8. External laser alignment lights
9. Patient couch
10. ECG gating monitor

CT Gantry –Internal structure

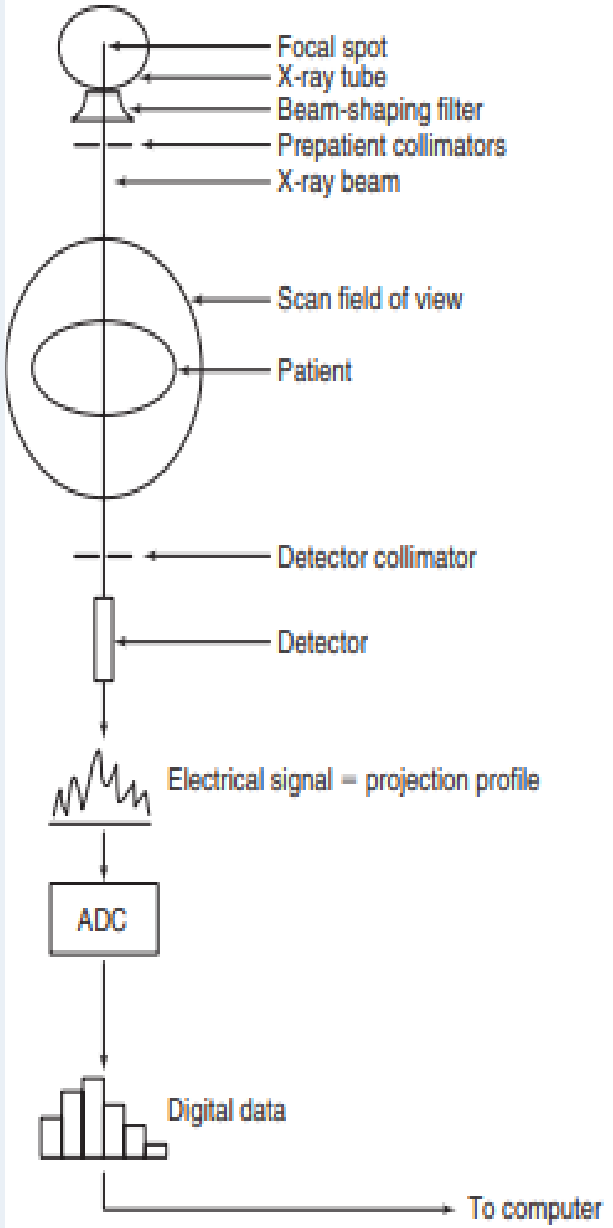


Label

1. X-ray tube
2. Filters, collimator, and reference detector
3. Internal projector
4. X-ray tube heat exchanger (oil cooler)
5. High voltage generator (0-75kV)
6. Direct drive gantry motor
7. Rotation control unit
8. Data acquisition system (DAS)
9. Detectors
10. Slip rings

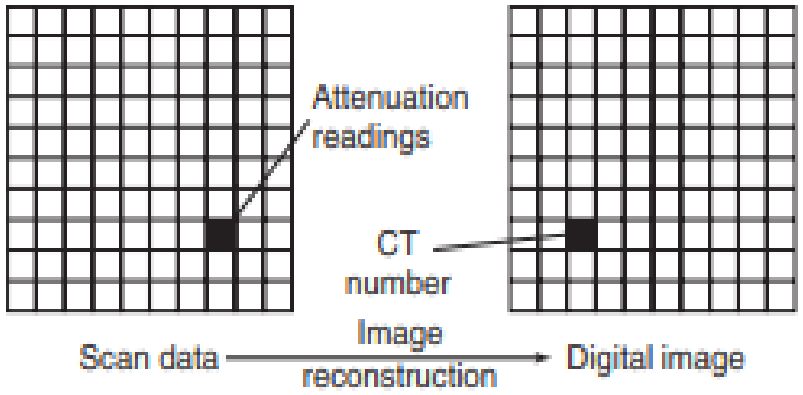
Operating Steps

1. The x-ray tube and detector are in perfect alignment.
2. The tube and detector scan the patient to collect a large number of transmission measurements.
3. The beam is shaped by a special filter as it leaves the tube.
4. The beam is collimated to pass through only the slice of interest.
5. The beam is attenuated by the patient and the transmitted photons are then measured by the detector
6. The detector converts the x-ray photons into an electrical signal (analog data).
7. These signals are converted by the analog-to-digital converter (ADC) into digital data.
8. The digital data are sent to the computer for image reconstruction.
9. Additional data corrections are performed on the data by using computer software.
10. The reconstructed image can then be displayed or stored on magnetic or optical tape or disks.



CT Numbers

As shown in Figure, each pixel in the reconstructed image is assigned a CT number. CT numbers are related to the linear attenuation coefficients (μ) of the tissues that comprise the slice (Table) and can be calculated as follows:



Tissues	Linear Attenuation Coefficient (cm^{-1})
Bone	0.528
Blood	0.208
Gray matter	0.212
White matter	0.213
Cerebrospinal fluid	0.207
Water	0.206
Fat	0.185
Air	0.0004

*At 60 keV.

$$\text{CT number} = \frac{\mu_t - \mu_w}{\mu_w}$$

where μt is the attenuation coefficient of the measured tissue, μw is the attenuation coefficient of water,
and K is a constant or contrast factor.

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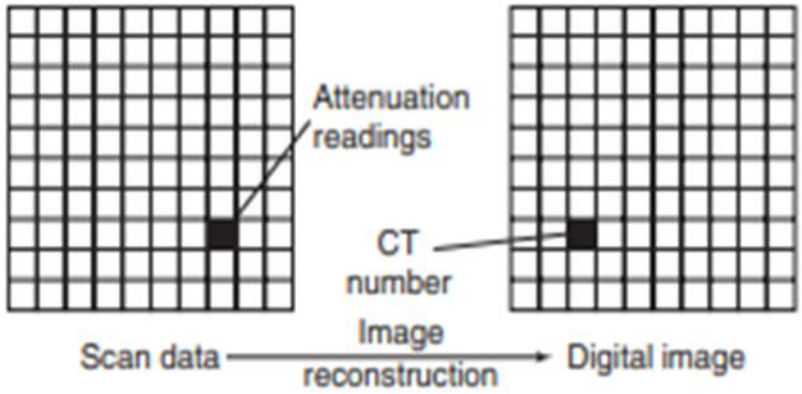

(H.W) At 73 keV, the linear attenuation coefficient for water is 0.19 cm−1. For example, if the linear attenuation coefficients for bone and water are 0.38 and 0.19 cm−1, respectively, and the scaling factor (K) of the scanner is 1000, the CT numbers for bone and water can be calculated:

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White matter	0.213
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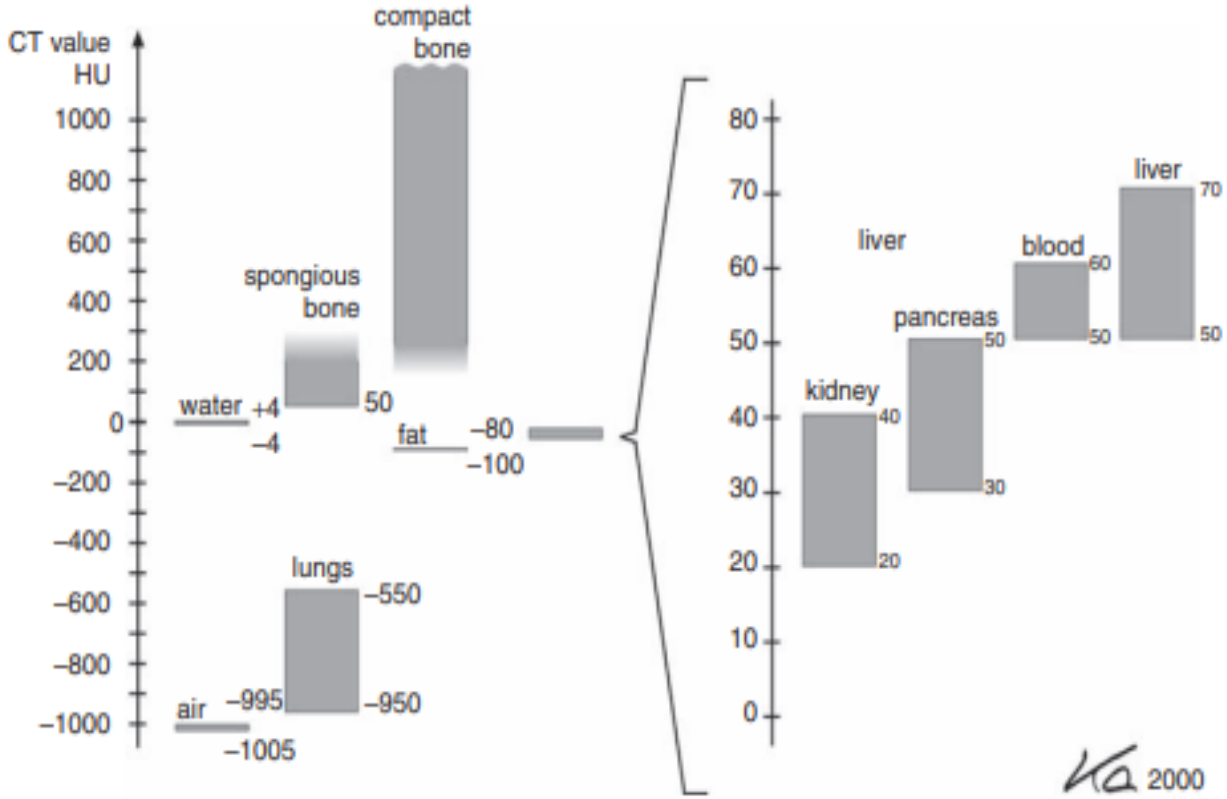
Water	0.206
Fat	0.185
Air	0.0004

*At 60 keV.

CT numbers are established on a relative basis with the attenuation of water as a reference. Thus the CT number for water is always 0, whereas those for bone and air are +1000 and −1000, respectively, on the H scale. Note the range of CT numbers for water, air, fat, kidney, pancreas, blood, and liver.



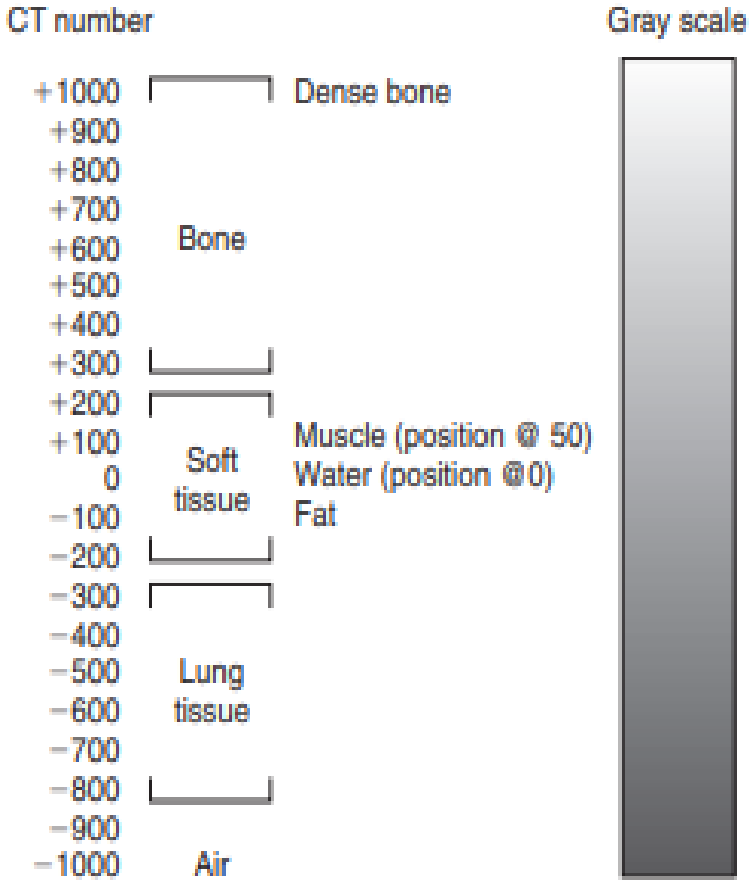
Bone and other calcifications with high atomic numbers and high density offer increased attenuation and therefore have higher CT values, typically up to 2000. This scale has no limit to the positive range of values. Therefore, we can say the following:

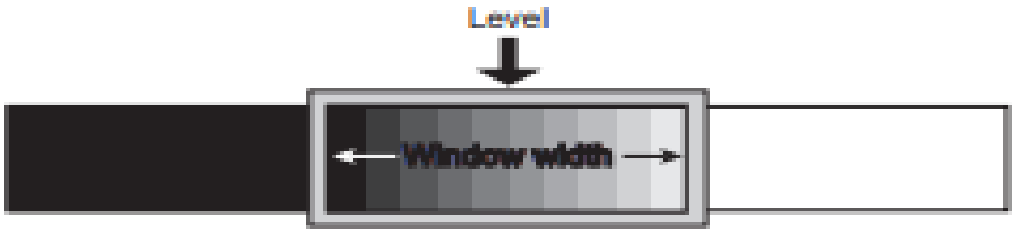
- Voxels containing materials that attenuates more than water (e.g. muscle tissue, liver, and bone) have positive CT numbers, whereas materials with less attenuation than water (e.g. lung or adipose tissues) have negative CT numbers.

Windowing

The CT image is composed of a range of CT numbers (e.g., +1000 to −1000, for a total of 2000 numbers) that represent varying shades of gray

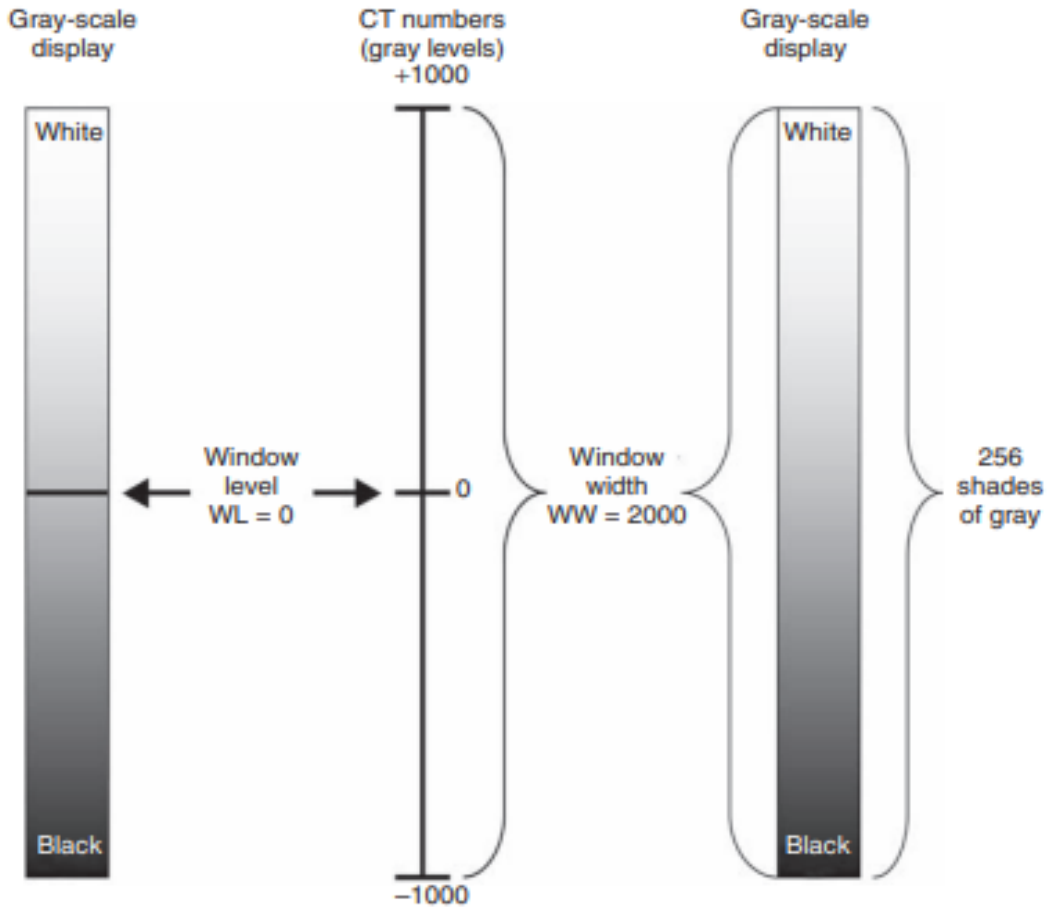
- the range of the CT numbers in the image is referred to as the window width. It determines the maximum number of shades of gray that can be displayed on the CT monitor.
- The window level is defined as the center or midpoint of the range of CT numbers (Fig. 8-3).
- Both the WW and WL are located on the control console.
- Although the WW controls the image contrast, the WL or C controls the image brightness.



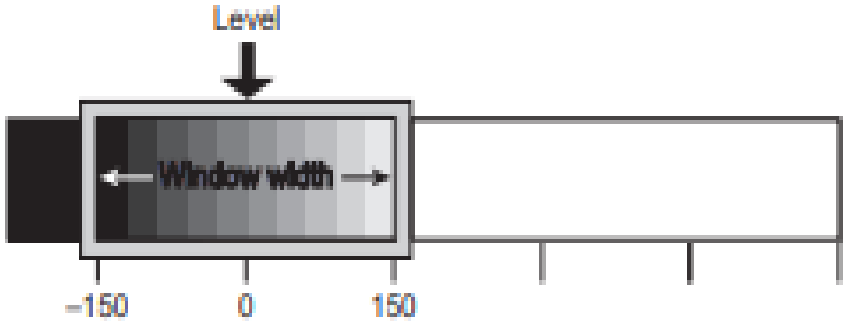


Windowing

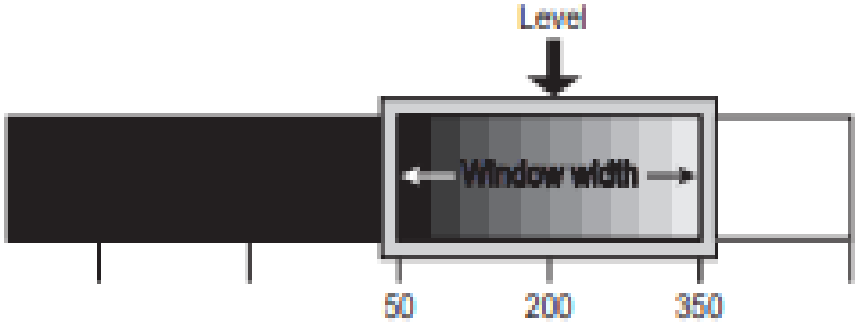
Windowing is a digital image post-processing operation intended to alter the image contrast (a function of the WW) and the image brightness (a function of the window center, C, or WL, as it is often referred).



If the window width is 300 and 0 is chosen as the window level, the Hounsfield values that are represented
as a shade of gray on this image will range from −150 to 150.

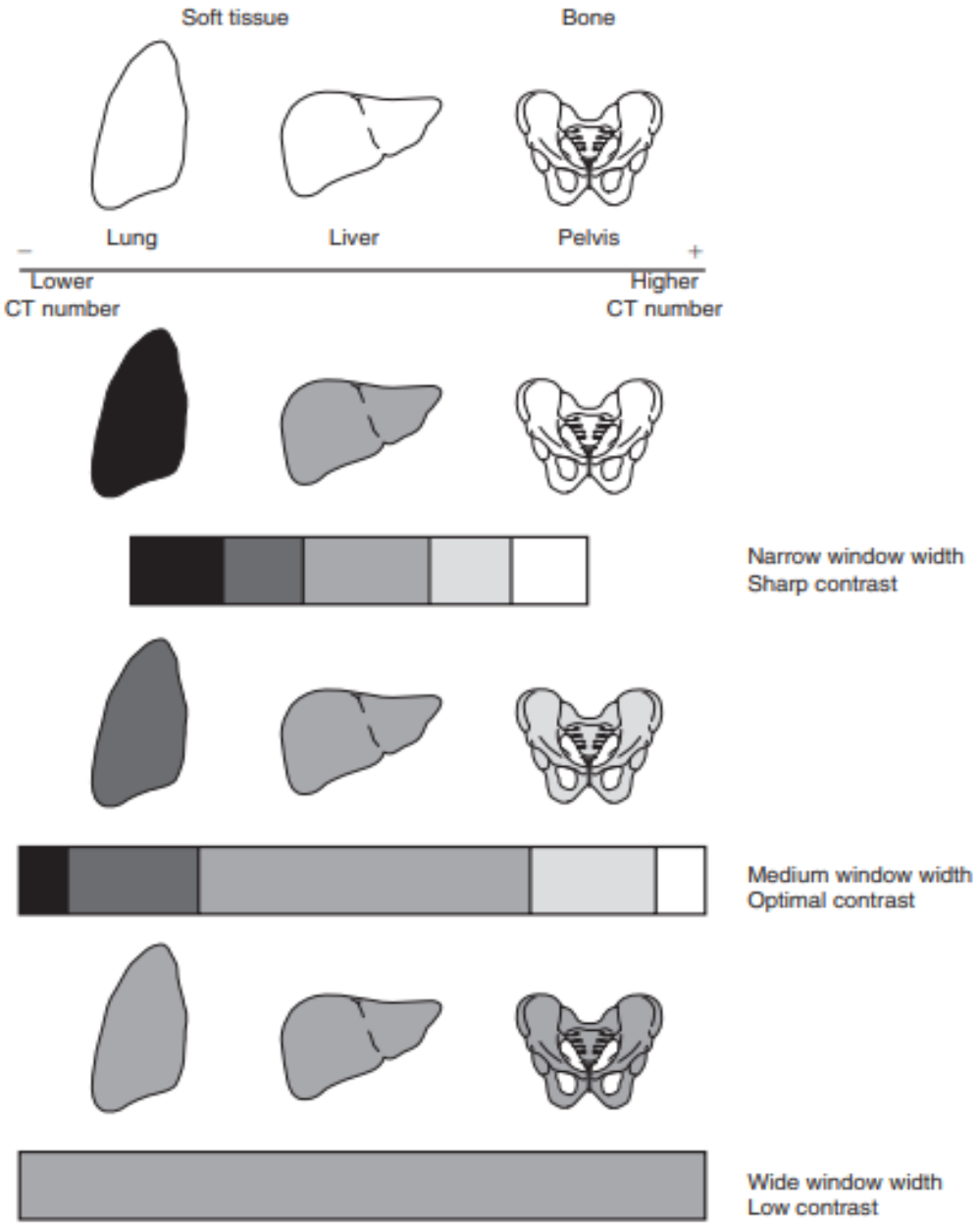


The width stays unchanged at 300, but the center is moved to 200. The new range of Hounsfield numbers to be included in the gray scale is from 50 to 350.



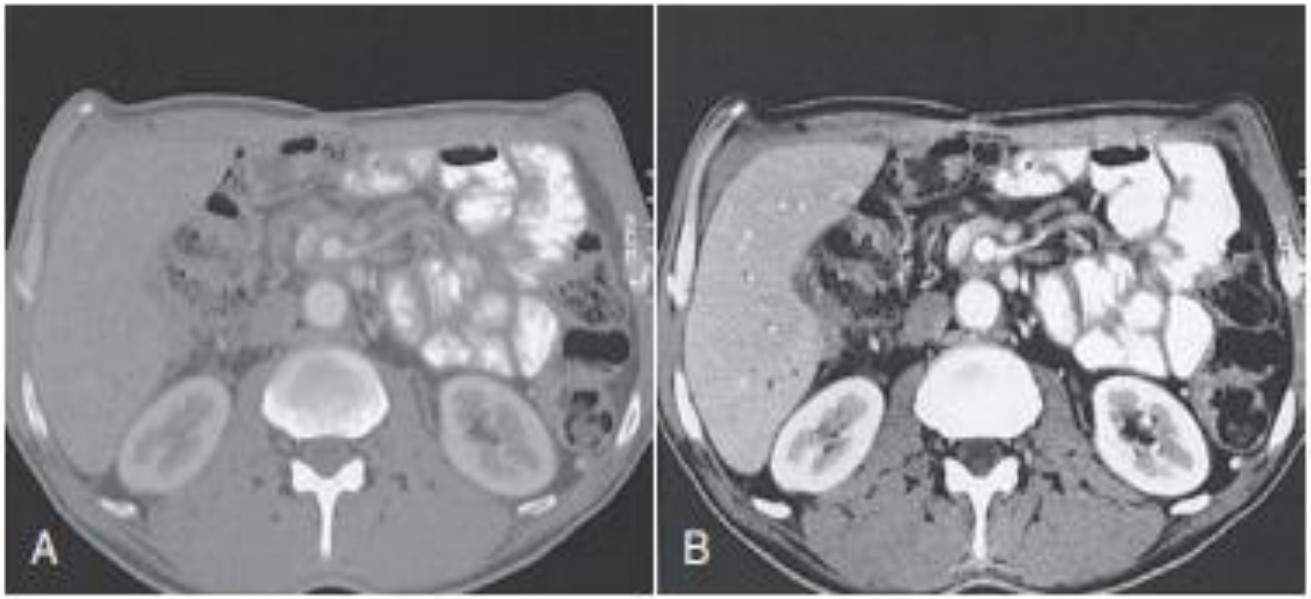
Effect of Window Width on Image Contrast

- When the WW is large (wide WW), the three different structures—the lung, liver (soft tissues), and pelvis (bone)—have the same gray tone.
- With a narrow WW, there is very sharp contrast to the point where the lungs appear black, bone appears white, and the liver is shown as gray tones.

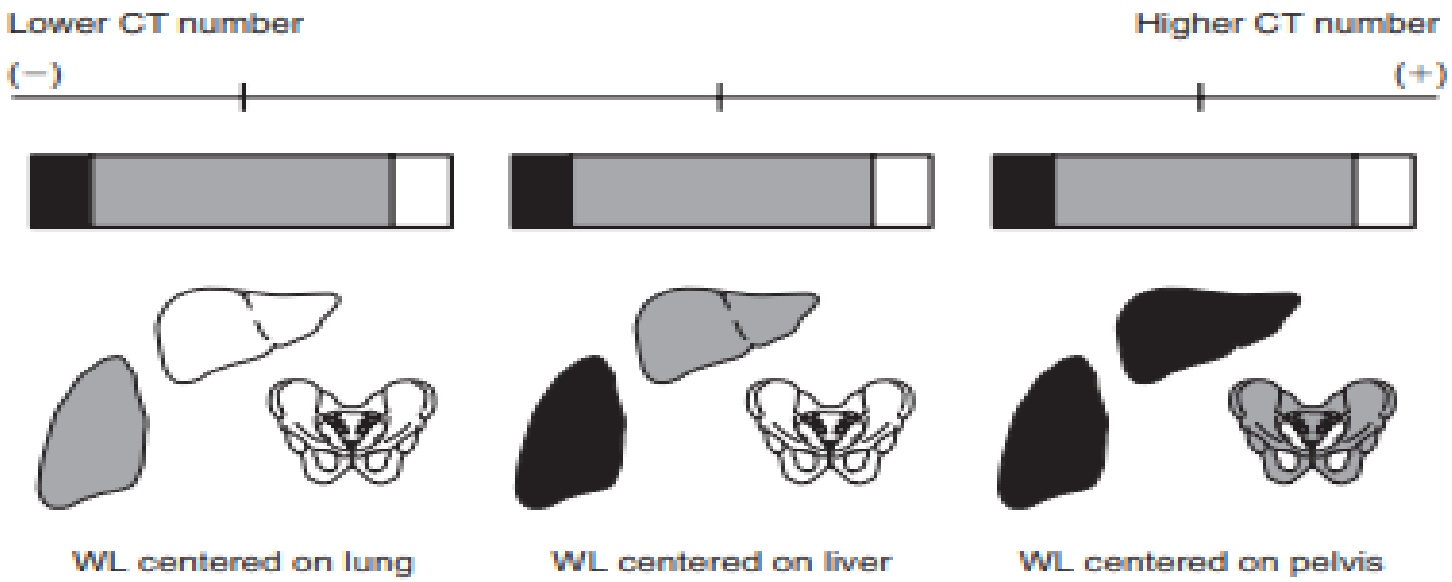


The effect of a wide WW (A)

narrow WW (B)

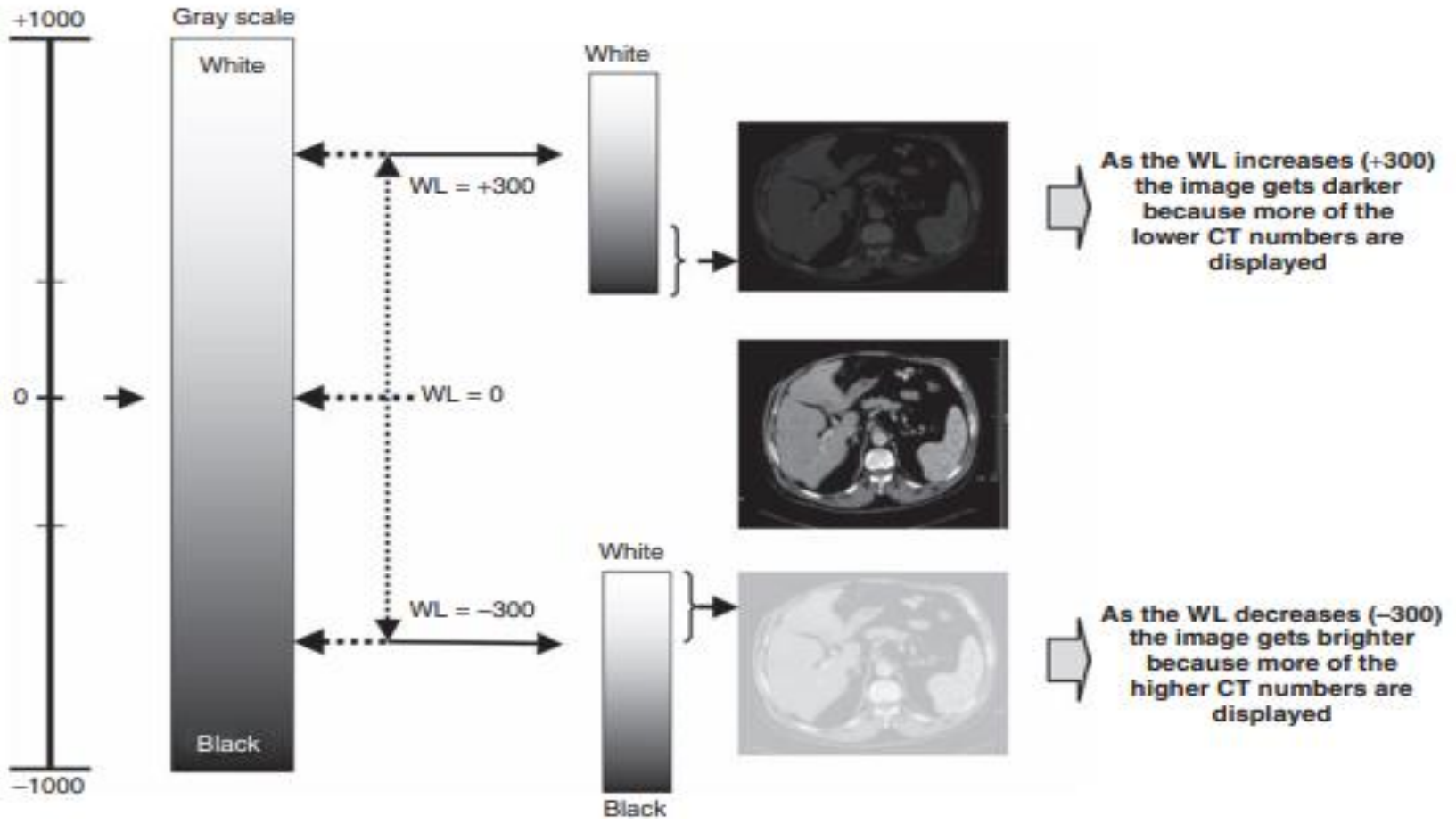


Effect of Window Level on Image Brightness



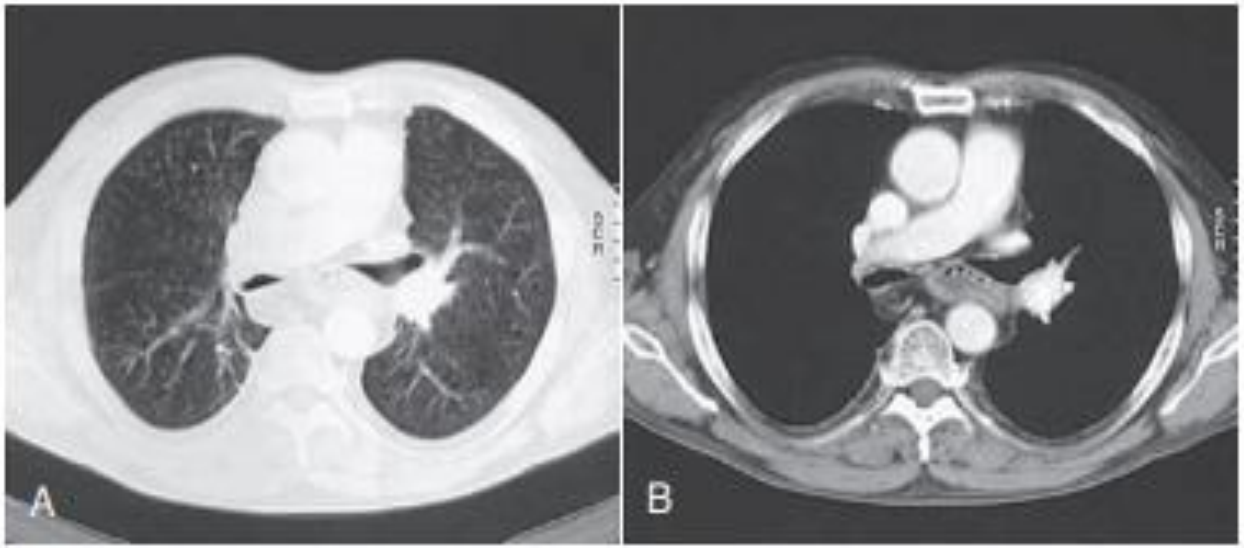
- when the WL is centered on the lungs (lower CT numbers), the image display is optimized for that structure, and the liver (soft tissue) and pelvis (bone) are displayed as white.
- On the other hand, when the WL is centered on the pelvis (higher CT numbers), the image display is optimized for the pelvis, and the lungs and liver appear black.
- Finally, with the WL centered on the liver (middle CT numbers), the pelvis appears white, and the liver is optimized for viewing.

- As the WL moves toward the higher CT numbers (generally white), more CT numbers with lower values (generally black) are displayed.
- In addition, as the WL moves toward the lower CT numbers, more CT numbers with higher values are displayed, and the image looks white



A, A lung WW of 1500 HU and a WL of −530 HU are used.

B, Soft tissue WW of 500 HU and a WL of +40 HU are



Typical Window Settings for Common CT Examinations

Examination	Width	Level
Head		
Posterior fossa	150	40
Brain	100	30
Temporal bone	2,800	600
Neck		
	250	30
Chest		
Mediastinum	350	50
Lung	1,500	−600
Abdomen		
Soft tissue	350	50
Liver (high contrast)	150	30
Pelvis		
Soft tissue	400	50
Bone	1,800	400
Spine		
Soft tissue	250	50
Bone	1,800	400