DISPLAY MONITORS

- Black-and-white or color monitors display the CT image.
- The display device within the monitor can be either a cathode-ray tube or some form of flat panel.
- The monitors used in CT require analog signals. Therefore, it is necessary to convert the digital signal from the computer's memory back to an analog format. Digital-to-analog converters (DAC) accomplish this task.
- The way an image is viewed on the monitor can be adjusted by changing the window setting.

WINDOW SETTINGS

- Window settings are largely subjective. They are also influenced by factors such as the patient’s size and body composition.
- Ideally, images would be displayed so that a different shade of gray was used for each Hounsfield value represented.
- However, there are more than 2,000 Hounsfield units, while the monitor can only display 256 shades of gray. Furthermore, the human eye can differentiate only a fraction of those shades.
- To solve the problem of more Hounsfield units than discernible shades of gray, a gray scale is used.
- Applying the gray scale, the display processor assigns a certain number of HU to each level of gray.
- The number of HU assigned to each level of gray is determined by the window width.

- If a wide window width is selected, for example 700, then 700 values must be distributed over the available shades of gray. Therefore, many HU are included in each shade of gray. This can make it difficult to discern subtle density differences on the image.
- The window width selects the quantity of HU to be displayed as shades of gray.
- By selecting the center value, the window level selects the range of HU that will be displayed.
- All values higher than those in the selected range will appear white on the image.
- All values lower than those in the selected range will appear black on the image.
- The window level should be set at a point that is roughly the same value as the average attenuation number of the tissue of interest.
- Wide window widths (500–2,000 HU) are best for imaging tissue types that vary greatly, when the goal is to see the various tissues on one image.
- Because wider window settings decrease image contrast, they suppress the appearance of noise.
- Tissue types with similar densities should be displayed in a narrow window width (50–500 HU). This will provide greater density discrimination and contrast.

IMAGE DISPLAY OPTIONS

- A region of interest, or ROI, is an area on the image defined by the operator.
- Placing an ROI is the first step in a number of image display and measurement functions.
The Hounsfield measurement of an object can provide valuable diagnostic information. However, because measurement may be negatively affected by volume averaging or image noise, caution should be used when Hounsfield values are used in the diagnosis of disease.

- If a cursor is placed on the image, the system will display the value for the pixel that is covered by the cursor.
- If an ROI is placed over an area, the reading is an average of the HU within the area.
- An HU reading derived from a single pixel can be useful in some instances, particularly when a quick check of a density is needed.
- ROI measurement should be used whenever the values will be considered in formulating a diagnosis. When an area is used, the standard deviation reading is also provided.
- The standard deviation indicates the amount of CT number variance within the ROI.
- A standard deviation of 0 indicates that every pixel within the ROI has the same HU. A standard deviation cannot be less than 0.
- The higher the standard deviation, the greater the variation among pixels within the region.
- Factors that produce a high standard deviation are:
  - Mixed attenuation tissue
  - ROI that includes streak artifact
  - Incorrectly placed ROI
- Distance measurements are helpful in reporting the size of an abnormality or when placing a biopsy needle. The software can also calculate the degree of angulation of the measurement line from the horizontal or vertical plane.
- The CT distance scale that often appears along the margins of an image can be used in the same way as a scale of miles is used in a map key.
- It is important to annotate images with any information that may not be immediately apparent.
- It is standard practice to include a reference image with lines posted to indicate the locations of each slice.
- Image magnification is not the same as decreasing the display field of view. Magnifying the image does not improve its image quality. It simply makes the image larger.
- Image magnification is often useful when acquiring distance measurements or placing an ROI. A larger image can make precise placement easier.
- Image magnification uses only image data (not raw data). Magnification is a useful tool that should be used on isolated images within a study.
- Magnification has inherent limitations and should not be used as an alternative to correct display field selection.

**Review Questions**

1. What is the function of the digital-to-analog converters?
   a. Converts the data into shades of gray to be displayed
   b. Converts the digital signal from the computer into an analog signal for the display monitor
   c. Converts the light emitted from crystal detectors into an electric current
   d. Converts the analog signal from the detectors to a digital signal for the computers

2. The window settings for Figure 4-1 are intended for evaluating:
   a. bone.
   b. mediastinum.
   c. lung.
   d. the contrast-enhanced heart.

3. Why is it necessary to convert the digitized data from the reconstruction processor to shades of gray?
   a. To allow an HU to be assigned to each structure
   b. To remove streak artifacts from the final image
   c. To enhance the desirable aspects of the image and suppress the undesirable aspects
   d. So that an image can be displayed on the monitor

4. What Hounsfield values are in the naturally occurring range (i.e., not manmade objects like surgical clips)?
   a. −1,000 to 1,000
   b. −600 to 0
   c. 0 to 1200
   d. −2,000 to 4,000

5. Decreasing the window width in a CT image decreases:
   a. slice thickness.
   b. mAs.
   c. the appearance of quantum mottle (image noise).
   d. the anatomic diversity displayed.

**Figure 4-1**
6. The window width of a specific CT image is set at 300, and the level (or center) is set at 100. How is a structure with a measurement of 280 HU displayed?
   a. It is white.
   b. It is a light shade of gray.
   c. It is a dark shade of gray.
   d. It is black.

7. If the main tissue of interest is liver, which of the following is the best approximate window level setting?
   a. −600
   b. 0
   c. 50
   d. 600

8. On a CT image an ROI is placed within a structure and measured. Its standard deviation is 0. What can be determined about this structure?
   a. It is composed of water or something with the same density as water.
   b. It is composed of fat.
   c. It is very homogeneous.
   d. It is very heterogeneous.

9. For which application are the raw data necessary?
   a. To magnify the image
   b. To decrease the display field size
   c. To create a histogram
   d. To obtain a Hounsfield measurement of a specific structure

10. A magnification factor of 1.5 is used to enlarge the image data, resulting in
    a. a decrease in the pixel size.
    b. an increase in the pixel size.
    c. an inaccuracy in any subsequent distance measurement.
    d. an image that is larger and may allow a more accurate cursor placement for measurements.