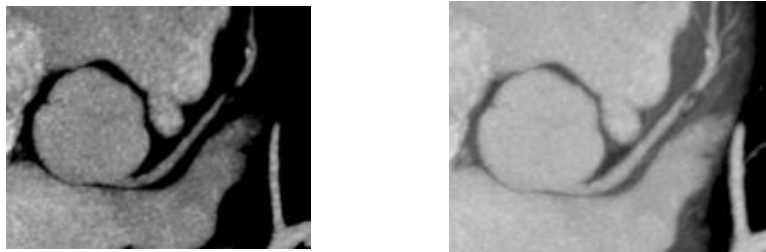


FINDING THE “TRUE” EDGE IN CTA

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Your patient has chest pain. The Cardiac CT Angiography shows plaque in the LAD. You adjust the viewing window trying to evaluate the stenosis but as you do the artery gets bigger or smaller. The more you fiddle the more confusing it becomes. How can an artery look like a ragged string in one view and then in a different window suddenly look so plump? What is the right window for making the diagnosis?

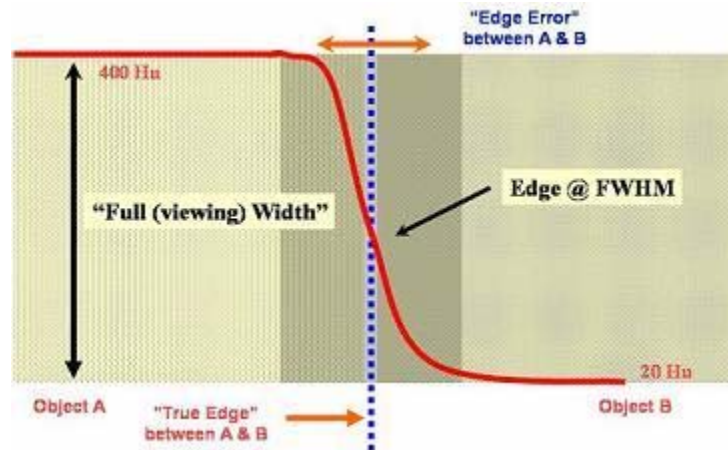


It comes down to finding the window width and level setting that gives you the most accurate representation of the true edge true edge between the contrast in the lumen and the wall of the vessel. Finding that view ultimately comes down to understanding a bit of the physics of CT image reconstruction and how a three-dimensional object like an artery is displayed on your 2-dimensional screen.

CT Angiography relies on the spatial resolution between a structure of high density (the contrast in the lumen) and another structure of much lower density (the artery wall and surrounding tissues). Typically, the contrast density in the lumen will be in the range of 250-450 Hounsfield Units (HU). The artery wall is usually around 20-60 HU and the surrounding epicardial fat will be about -20 to -80 HU. Displaying such widely varying densities creates the potential for significant variability in where the edge is visualized on the screen, depending on the window width and level settings.

In a CT image, the border between objects is composed of an array of pixels (or voxels, in a 3-D image) that render the image as an array of gray scale densities. From a distance, these objects are distinct, but up close, the borders are actually a blur. The true edge is distinct in physical space but in “image space” there is a transition over a finite dimension.

The “edge” can be defined set by the concept of the Full Width - Half Maximum (FWHM). The FWHM means that the edge is drawn at the boundary where the CT density is halfway between the maximum densities of each of the separate objects sharing a common edge.



So, if the contrast in the lumen has a density of 400 HU and the vessel wall has a density of 20 HU (a width of 380HU) the “true” edge will be displayed at the point where the density is 210 HU (the point halfway between the minimum and maximum densities). That will be our reference edge and the point that we should be aiming to actually see on the screen as the displayed edge.

Changing the window width and level will change the how the edge is actually visualized on your screen and will therefore affect the apparent size of a vessel. This will also affect where we perceive the edges of the lumen, vessel wall and plaque to be. Measurements of distance on CT scans are extremely accurate but are only as good as how accurately we place the cursor when we make our measurements. Changing the apparent edge can dramatically affect the accuracy of where we place the beginning and end of our measurements.

To understand how this will affect the perceived edge it is important to have a basic understanding of the meaning of window width and level.

CT Scans are displayed as gray-scale images. The data can be displayed in as many as 4096 shades of gray. By definition, water has a density of 0 HU. Air is -1000 HU and dense bone is +1000 HU.

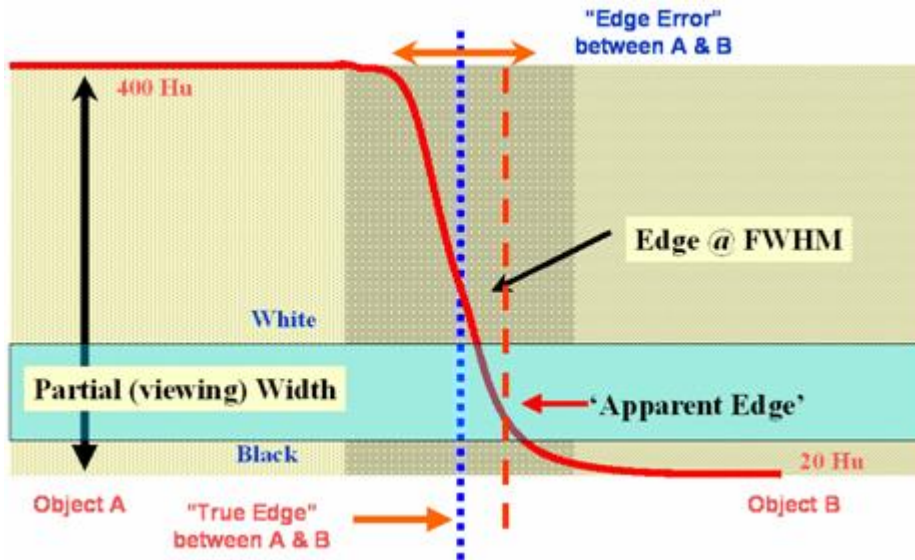
However, the human eye can, at best, perceive about 20-30 different levels of gray at a time. In order to accommodate the limitations of our vision it is helpful to define a range of densities to display rather than trying to view the full spectrum at once. This is set as the window width and level.

The window level is the center point of the range of densities to be displayed.

The window width is the range of densities to be displayed in gray-scale from white to black. Any densities below that range will be displayed as black and any densities above that range will be displayed as white. In effect, the window width expands a narrow range of gray-scale that is too

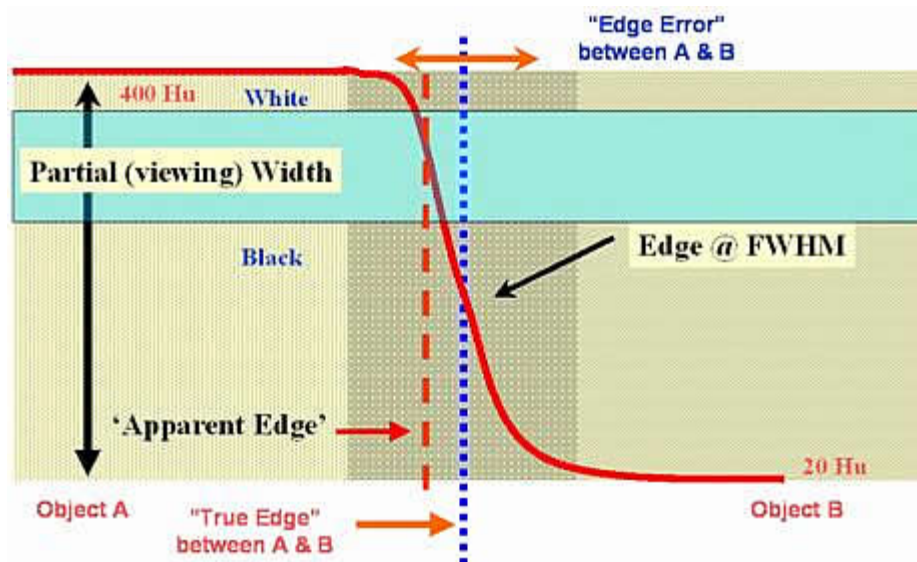
subtle for us to perceive into the full spectrum of black to white.

If we set the window level at 60 HU and the width at 100 HU, any pixels that represent densities below 10 HU will be black and those above 110 HU will be white.



If we apply that setting to our CT image with a lumen opacified to 400 HU and the vessel wall at 20 HU it becomes apparent that the “perceived” edge of the vessel wall will move away from the “true” edge as defined by the Full Width – Half Maximum. The “true” edge is at 210 HU but in this window setting all the pixels over 110 HU will be white, thereby including some of the pixels that are between the “true” edge and the “perceived” edge and increasing the size of the lumen.

Conversely, setting the window level at 380HU with a width of 300 HU will display pixels between 230 HU and 530 HU. This will move the “perceived” edge to the opposite side of the “true” edge.



Now a pixel must have a density of 530 HU or more to be displayed as white. Pixels as high as 230 HU will appear black even though the “true” edge is at densities as low as 210 HU. This will effectively make the lumen appear smaller.

So, even though the scan may be able to determine where the actual edge of the lumen is, within the limits of its spatial resolution, changes in the window level and width can make the lumen appear larger or smaller and change our perception of the actual location of the lumen-vessel interface.

Then how do we set the window width and level to ensure that we are getting the most accurate view of the lumen?

In general, setting the window level to the Full Width- Half Maximum will be the most reliable. This will ensure that regardless of the window width, the “true” edge at the FWHM is displayed. This can be determined by switching the image to an MPR view. (Hounsfield Units can not be determined in a MIP view as that view represents a “slab” of voxels of different densities. An MPR view will be only 1 voxel thick). Create a Region of Interest (ROI) in the center of the artery lumen and another ROI outside the lumen in the artery wall or plaque. The FWHM is the point halfway between these values.

Bringing the window width down to 2 will create a binary image. All pixels greater than the window level will be white and those under will be black. This will display the edge at FWHM and will closely approximate the measurements made by software tools that automatically define the lumen.

Increasing the window width to at least 3-4 times the window level (but not changing the level from the FWHM value) will generally provide an image that is acceptable for visual evaluation of the

lumen and also allows visualization of other structures of variable density surrounding the 'edge' (such as calcification and/or non-calcified plaque).

In our [Level II](#) and [Level III](#) training programs, we emphasize the value of a clear understanding of imaging physics. Applying the principals of 'edge detection' and window width and level allows the reader to arrive at the proper diagnosis. Although CTA has an incredible negative predictive value for obstructive disease and characterization of plaque characteristics, edge definition become the most important and critical factor for clinical decision making when the lumen appears narrowed (i.e. 'obstructed'). Failure to understand the limitations and artifacts inherent in image interpretation on the scale of the coronary arteries can significantly impact your ability to separate non-obstructive from obstructive disease.