

## Hybrid Calibration and Display of CT Images in the Gram Scale: Can We Ever Give up the HU Unit?

The Hounsfield unit (HU) of CT images is computed with reference to distilled water and air at standard temperature and pressure (STP). These water calibrations are made with idealized, circular, water or water equivalent phantoms. Since the atomic compositions of soft tissues are close to water and the patients somewhat oval in shape, the HU scale has served well for subjective image viewing for approaching 4 decades. Specific human bodies can however have large differences in size, shape and composition relative to the water phantoms.

Even with homogeneous phantoms, HU units are known to vary from scanner to scanner, tube changes, manufacture software, table height, slice thickness, FOV, kVp, filtration, and other scan parameters. One phantom study for example found differences of 7 to 73 HU for the same target on 8 scanners. HU values also vary with the patient's physical composition including shape, size, and bone/muscle/fat ratios. HU reliability with MDCT is further reduced from higher scatter and beam inhomogeneity, proprietary scatter correction methods, greater demand on beam shaping and maintaining subjective image quality. The CT scanner point-spread-function (PSF) produces errors in HU values for small objects and the edges of large ones. The measurement accuracies of dimensions, areas, and volumes can be greatly reduced. The partial volume error based on voxel size is well recognized but a 'PSF volume error' may be defined that is even larger. Because of all of these variations, the residual errors that remain after water calibrations are of sufficient magnitude to degrade many quantitative CT measurements, especially for higher z materials such as calcium and iodine. The advancement of quantitative CT applications requires more advanced calibration methods for improvements in accuracy, precision, and standardization of measurements of HU (or mass) and dimensions.

This talk will explore a new CT calibration method (Hybrid calibration) and a new density scale to replace the water scale. The Hybrid calibration method provides images with voxel intensities expressed in density units ( $\text{mg}/\text{cm}^3$ ). The calibration method uses in vivo fat/muscle or blood to calibrate for soft tissue densities. The calibrations are therefore scan and patient specific. Higher z targets (calcium, bone, iodine, etc.) are also calibrated for beam energy using phantoms scanned simultaneously with or independent of the patient. The Hybrid calibrated images are displayed with voxels and W/L settings expressed in  $\text{mg}/\text{cm}^3$  units in place of HU values. A density scale for image display is proposed that emulates the current HU scale and would require minimal training or changes for image display and reading. The use of these methods in coronary calcium scoring and bone densitometry will be demonstrated.

### Learning Objectives:

1. Learn the limitations of water calibration for quantitative CT applications.
2. Basic understanding of a new, non-water based calibration method.
3. Understand the problems of quantitative CT of small and large calcium or iodine targets.