# Clinical Note

Calibrate Your Treatment Planning System to Patients, Not Plastic


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## Background

Calibrating a Treatment Planning System (TPS) to plastics, rather than patient-like materials, can result in dosimetric errors. Understanding the reasons behind this is key to improving TPS dose agreement.

In radiation therapy treatment planning, CT data is commonly used both to define the patient's anatomy and to provide tissue density information. Accurate planning, and ultimate delivery, of the treatment is contingent on correctly calibrating the TPS to a CT scanner.

## Understanding CT Calibration Curves

While there is an apparent simplicity to CT calibration curves, the underlying physics is more complicated. The HU values reported by CT scanners do not, as a rule, behave linearly or even bi-linearly versus density across an arbitrary selection of materials. In fact, there is substantial dependence on the atomic number, especially as the effective atomic number increases above water.

The reason that calibration curves work is that the calibration is not designed for all materials, but a reduced set of body-like materials. This effectively reduces the complex HU-response of CT scanners to a more well-behaved, monotonic calibration. This requires a set of body-like materials, which are conveniently defined in standards like ICRU-44 and ICRP-23 and provide guidance on the elemental composition of bodily tissues. Calibrating a CT scanner to materials reflecting ICRU-44 and ICRP-23 definitions means that the calibration curve will likely be appropriate for patients. On the other hand, calibrating a TPS to non-body-like materials can result in incorrect dose delivery to a patient.

**The easy solution for clinics is to ensure that CT-to-Density calibrations are being performed based on ICRU-44 and ICRP-23 based Tissue-Mimicking Materials,** rather than plastics such as Teflon and Delrin that do not necessarily respond similarly to bodily tissues in a CT scanner.

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## Clinical Example

Figure 1 shows the difference between planning based upon a calibration using body-like materials versus a calibration curve based on materials such as Teflon and Delrin (Verhaegen, et al.[1]). The latter materials have been used as proxies for bone based upon their higher densities, but their effective atomic number, and ultimately HU values, are generally inconsistent with bony tissue. If a TPS is using the lower calibration curve based on ICRU-44 definitions, indicated by the green arrow (added by Sun Nuclear, for emphasis), a given tissue around 550 HU will map to a patient density of around 1.3 g/cm$^3$. Using the upper calibration curve, indicated by the red arrow (added by Sun Nuclear, for emphasis), which is based upon Teflon rather than tissue mimicking materials, the TPS would map this same voxel to a density closer to 1.7 g/cm$^3$. The impact of this is overestimating patient density, which would lead to delivering too much energy, resulting in a higher dose than intended. The Verhaegen paper quantified these dose errors in some regions to be up to 10% for 6 and 15 MV photons and 30% for an 18 meV electron beam.

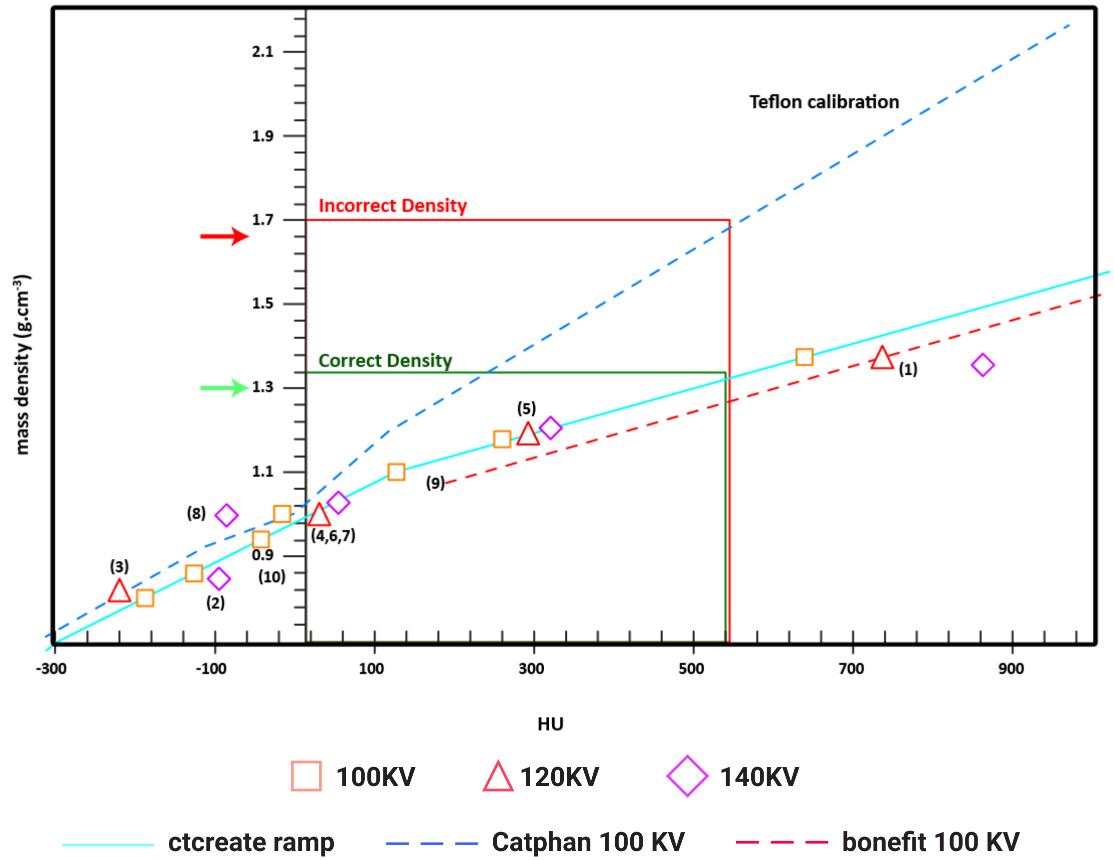


Figure 1 – Difference between planning based upon body-like materials vs Teflon and Delrin

## Mimicking Tissue for Higher Accuracy in CT-to-Density Conversion

This systemic uncertainty is complex in nature, but can be easily corrected. The Advanced Electron Density Phantom from Sun Nuclear includes HE Inner and Cortical bone inserts as well as others that closely match ICRU-44 and ICRP standards for human tissue densities. To learn how this phantom offers assurance that calculation of energy from CT to TPS is highly precise, click here.

[1] F. Verhaegen and S. Devic, Sensitivity study for CT image use in Monte Carlo treatment planning, Phys. Med. Biol. 50 (2005) 937-946

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