Purpose: To quantify the influence of material heterogeneities for brachytherapy dose calculations.

Method and Materials: Current brachytherapy treatment planning systems (TPS) use the TG-43 dose calculation formalism. This formalism uses the superposition principle with single-source dose distributions in liquid water, and is used for all conventional brachytherapy sources (both low-energy and high-energy photon emitters). In the high-energy regime, dosimetric sensitivity to media heterogeneities in comparison to water is less significant than for low-energy sources. To quantify these effects as a function of photon energy, a series of Monte Carlo (MC) based radiation transport simulations was performed using the MCNP5 code. For simplicity and generalization, brachytherapy sources were approximated as point sources in spherical phantoms, with isotropic mono-energetic photon-emitting point sources to approximate photon energies from common radionuclides. The first simulation series was a homogeneous water phantom used as the reference geometry, and was compared to two different heterogeneous phantoms selected with consideration to photon energy. The low-energy heterogeneous phantom used breast tissue for $r \leq 3$cm, cortical bone for $3.0 < r < 3.3$cm, and water for $3.3 \leq r \leq 15$ cm. The high-energy heterogeneous phantom used lung tissue for $6 < r < 10$cm and iron for $15.0 < r < 15.5$cm with water everywhere else out to 40cm.

Results: Dose to medium-in-medium (D_{MM}) for low-energy sources differed by –20% in breast and by a factor of 4-7 in bone, while dose to water-in-medium (D_{WM}) differed by +30% and –50, respectively. For high-energy sources, D_{MM} differed by –21% to +8% in lung and similar amounts for D_{WM}. In iron, D_{MM} differed by a factor of 20–1.8 for 50–662keV, but by <30% for D_{WM}. Using spherical geometry maximized the influence of material heterogeneity due to scatter.

Conclusion: Brachytherapy dose calculation accuracy using the TG-43 formalism is challenged by material heterogeneities, resulting in errors exceeding an order of magnitude under certain conditions.