Purpose: To investigate, by means of Monte Carlo (MC) simulations, the relationships of the dose to a local medium, \( D_{m,m} \), and the dose to a water cavity embedded in the medium, \( D_{w,m} \), the dose to a cell in the medium, \( D_{c,m} \) and the dose to a cell nucleus in the medium \( D_{n,m} \) for different energies used in brachytherapy and different cavity sizes.

Methods: The Geant4 9.3 MC package was used to calculate \( D_{m,m} \), \( D_{w,m} \), \( D_{c,m} \) and \( D_{n,m} \) for a mono-energetic photon beam impinging on one side of a cubic phantom. Concentric spherical cavities of 2-14 mum representing cells and their nuclei with four different chemical compositions were placed inside the phantom. Absorbed dose and electron fluence inside the cell and nucleus were scored. The dose to the cytoplasm and nuclei cavities was also estimated by means of large cavity theory (LCT) and small cavity theory (SCT) calculations.

Results: Low brachytherapy energies are more sensitive to chemical composition of the cytoplasm and nucleus. Three of the simulated cell lines have water-like behavior for adipose tissue while for breast and bone tissue the variations are larger. One cell line deviates for all the simulated tissues. Estimated results calculated with SCT deviates from MC calculated results for the low energies up to 50 keV for 2, 3 and 5 mum nucleus. For the 7 mum nucleus the difference is large up to 300 keV. The largest differences between LCT and MC results are observed for energies up to 100 keV.

Conclusions: There is no universally applicable set of conversion factors used to convert \( D_{m,m} \) into the dose received by the cell nuclei. Water equivalent behavior varies depending on the chemical composition of the cell and nucleus and the surrounding tissue.