A SPECT/CT dosimetry phantom for beta-emitting radionuclides in liquid solution was designed and constructed. The phantom features inserts that are compatible with different dosimeters and detectors for measurement-based dosimetry. Initial testing of the phantom was performed using ^{99m}Tc in its fill volume. Monte Carlo modeling of the experiment and detectors was performed using the EGSnrc user code egs_chamber. Measurements from a thimble type ion chamber and TLD100 microcubes agreed within k = 1 uncertainty bounds. Measurements from an electron field diode were found to agree with Monte Carlo estimates in one experiment but differ by as much as 20 % -30 % in another. Measurements performed on ^{177}Lu and ^{131}I in a redesigned experimental setup using a parallel plate ion chamber, electron field diode, radiochromic film, and thin TLD100 chips were found to agree with Monte Carlo predictions within k = 1 uncertainty values except for the ion chamber in one of the ^{131}I experiments. Here differences in measured and predicted values were found to be as high as 16 %. Uncertainties on the ADW measurements were generally between 5 % - 8 % while uncertainties in the predicted doses were typically between 7 % - 9 %. The exception to this was the uncertainty in some of the film measurements, which could be as high as 27 % depending on the location of the film in the dosimeter probe. Experiments using miniature check source phantoms for validation of dose estimates across bone, lung, and water equivalent interfaces were performed using EBT3 film for ^{177}Lu and ^{90}Y. Measurements were found to agree with Monte Carlo dose estimates within k = 1 uncertainty bounds for all interfaces for both radionuclides except for the bone to water interface for ^{177}Lu where a small air gap due to machining was present near the interface. Uncertainties in the film measurements were found to be as large as 25 % to 30 % due to uncertainty in film positioning with respect to the interface and depth in the phantom combined with small ROI voxel sizes. Despite this, depth dose profiles were in generally good agreement with average dose differences for ^{90}Y being as low as 8.5 % for bone, 2.5 % for water, and 3.3 % for lung. Through this work, methods for performing measurements on liquid solutions of beta-emitting radiopharmaceutical therapy agents using dosimeters with calibrations from a NIST-traceable x-ray beam were established and compared with Monte Carlo absorbed dose to water estimates.