Purpose: To examine the relationship between the primary SCERMA, $S_p$, and the primary collision KERMA, $K_{cp}$, as a function of depth for clinically relevant energy spectra, and to accurately model the SCERMA to KERMA ratio (SKR) for clinical photon beams.

Methods: $S_p$, $K_{cp}$, $S_p / K_{cp}$ (≡SKR) for the energy spectra of Cobalt-60 (Co-60), and Mohan 4 MV, 6 MV, 10 MV, 15 MV, and 24 MV photons are analytically calculated over depths from 0 to 40 centimeters in water. The $S_p$ and $K_{cp}$ are fitted to exponential functions, $S_p0\exp(-\mu'd(1-\tilde{d}))$ and $K_{p0}\exp(-\mu d(1-\tilde{d}))$, respectively, with depth $d$, linear attenuation coefficient $\mu$ and beam hardening coefficient $\eta$; $\mu'$ and $\tilde{d}$ are the corresponding quantities for $S_p$. The relationships between $\mu'$, $\tilde{d}$, SKR vs. $\mu$ are examined. Trends between the fitting parameters and $\mu$ were also determined, and the results applied to model the SKR of 6x and 15x clinical beams as functions of only $\mu$, $\tilde{d}$, and depth.

Results: SKR decreases with depth for all spectra. We found $\mu' = (0.80496 + 4.8748\mu)\mu + 0.005736$ and $\tilde{d} = (0.13076 + 2.6571\mu)\mu + 0.0036151$ for $0.0273/cm = \mu < 0.0392/cm$, and $\mu' = 0.87718\mu + 0.010864$ and $\tilde{d} = (0.009 + 0.50122\mu)\mu + 0.0037$ for $0.0392/cm = \mu = 0.0667/cm$. This model predicts the normalized SKR/SKR($d=0$) with a relative deviation of 0.1% and max deviation of 1%. SKR/SKR($d=0$) from clinical beams 6x and 15x is examined to be in agreement with analytic computation from spectral data with 1% and 0.5% maximum error, respectively.

Conclusions: Knowledge of normalized SKR is necessary to calculate scatter dose. We have developed an empirical model to calculate the normalized SKR to be used for clinical (scatter) dose calculation and consequently improve dose calculation accuracy.