Purpose: Due to multiple Coulomb scattering in complex geometries, small field dosimetry in proton therapy is challenging. Our goal was to define an indicator for the accuracy of dose delivery based on analytical dose calculations in treatment planning systems for small (e.g. radiosurgery) proton therapy fields.

Methods: Seven patients whose treatment involved one or more small fields (below ~3.6cm in diameter) were selected. We developed a fast methodology to quantify the inhomogeneity of the tissue traversed by a single beam using a heterogeneity index (HI). The implementation was based on the dose calculation approach taken by our pencil beam algorithm. Plans created with the treatment planning system were verified against Monte Carlo dose calculations on a field-by-field basis. DVHs were analyzed and differences in the dose to the GTV were assessed. The correlation between the HI-values and the discrepancies between planning system and Monte Carlo in terms of absolute dose to the target was studied.

Results: Our treatment planning system overestimates the dose within the GTV for very small fields by up to ~8%, even if proper output factor normalization is done in water. The differences are strongly correlated to HI (Spearman's $\rho=0.8$, $\rho<0.0001$). More complex heterogeneities within the beam path caused larger errors by the analytical algorithm. With the established correlation a threshold for the HI can be set by choosing a tolerance level.

Conclusions: The HI as defined in this study appears to be a good indicator of the accuracy of proton field delivery in terms of GTV prescription dose when small fields are being delivered. Each HI-value was obtained in less than 2 minutes allowing implementation of the HI algorithm in clinical routine. For HI-values exceeding a certain threshold, either a change in beam incidence or a Monte Carlo dose calculation should be considered.