Purpose:
Due to range uncertainty and its interplay effect with setup error and internal tissue heterogeneity, proton beams usually use a large distal and proximal margin, especially when the distal margin falls in a low density tissue, such as lung. As a result, beam angle selection is very important for proton therapy. In this study, we incorporate beam-specific planning target volumes (bsPTVs) into a beam angle optimization process to minimize required treatment volumes for each beam and combination of two beams along with other dose restrictions to the organ at risks (OARs) in the beam path.

Methods:
The bsPTVs were constructed for each beam angle over 10 degrees interval by taking into account both the range and setup error. Subsequently, doses from each beam angle were approximated using analytical dose model assuming uniform-dose distribution throughout the target volume. The objectives set included the volume of bsPTV for each beam, the volume of intersection between multiple bsPTVs, and mean doses to OARs in the beam path.

Results:
A software tool was developed and applied to optimize two-beam arrangement for a lung cancer patient. Objectives were plotted as figure-of-merits in color maps and bsPTVs were overlaid on axial CT images to assist the interpretation of results and the eventual angle selection.

Conclusions:
We found that the intersection of beam-specific PTV is a convenient tool for minimizing the combined high dose volume by selecting the best combination of beam angles. Our visual tools that display trade-offs between different objectives were found helpful for angle selection as well as the interpretation of results.

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