Factors affecting the selection of beam directions in proton therapy.

The physical characteristics of protons dictate that the criteria for selecting incident beam angles will be somewhat different to that of photon treatments. Three main criteria can be identified: the geometrical relationship between critical structures and the target, the reduction of integral dose and the avoidance of gross density heterogeneities. The lateral edge of the beam can best be used to avoid critical structures. Conversely, sparing of structures using the distal edge alone should be used with caution due to uncertainties in the absolute range of the beam in the patient. However, the distal fall-off can be used to reduce integral dose, and the level to which this can be achieved will, in contrast to photons, be strongly dependent on the incident beam direction. Of at least equal importance is the need to reduce the effect of gross tissue heterogeneities on the delivered dose distribution. We have found that they can have a number of degrading effects on the quality of a plan. They can affect the accuracy of the calculated dose, degrade the level of dose conformation that can be achieved and enhance the sensitivity of a plan to delivery uncertainties. To aid the planner in selecting beams, a simple index for quantifying density heterogeneities has been developed which has some potential in predicting the magnitude of these effects. The identification and quantification of such criteria will aid the development of comprehensive tools for the optimisation of proton plans.