AbstractID: 7002 Title: Reducing Uncertainties in Proton Therapy – Achieving "What You See is What You Get"

An important characteristic of protons is that they are expected to stop at a well-defined depth and, being heavy, deviate minimally from a straight path. Proton dose distributions computed with the aid of commonly used treatment planning systems, especially for intensity and energy-modulated proton therapy (IMPT), exhibit exquisite target dose conformality and dose homogeneity and normal tissue sparing. However, the dose distribution actually received by the patient may be significantly different from what is seen on the original treatment plan. This is, in part, due to various sources of uncertainties and approximations. Examples of these sources include: daily treatment setup; inter-fractional anatomical variations; intra-fractional internal movements of organs; dose calculation approximations, especially in the presence of complex tissue heterogeneities; and CT number variability and the uncertainty in their conversion to stopping powers. These uncertainties lead to a lack of full confidence in computed dose distributions. Furthermore, proximal, distal and lateral margins are larger than what would ultimately be achievable. Often, desirable beam directions towards sensitive organs just beyond the intended range of protons are avoided as is the use of protons in the thorax and abdomen. Therefore, the optimum dose distributions possible with protons are not often achieved. Another consequence of limited accuracy is that the response of tumors and normal tissues cannot be reliably correlated with dose distributions. Most of the same uncertainties are also present in photon dose distributions; however, their impact is greater on proton dose distributions due to greater sensitivity of protons to perturbations caused by these uncertainties. Improvement in accuracy of both computed and delivered dose distributions, necessary to exploit the full potential of proton therapy, can be achieved through a variety of means. Examples include (a) mitigation of the impact of intra-fraction motion through respiratory gating; (b) computation of composite ("4D") dose distributions taking respiratory motion into consideration; (c) computation of cumulative dose distributions using repeat 3D and 4D CT to take inter-fractional changes into consideration; (d) reduction in CT number uncertainty and in image artifacts caused by high Z materials through improved CT calibration, novel imaging techniques and reconstruction methods. In addition, if the repeat CT during the proton therapy course reveals that the inter-fractional anatomic changes are significant, adaptive replanning of treatments at appropriate times may be performed to assure that the original intent of the treatment plan is met or exceeded. Clinical examples will be presented to illustrate the impact of selected uncertainties in the current state of the art and the gains to be made with the improvement in accuracy in each of the areas identified above.

Educational Objectives:

1. Understand the sources of uncertainties in proton therapy

2. Comprehend the extent of the impact of these uncertainties on the differences between computed and delivered dose distributions.

3. Become aware of the strategies to improve accuracy and learn about the resulting dosimetric and potential clinical gains.