

Target and normal tissue motion during intensity-modulated radiotherapy (IMRT) delivery results in unplanned over-and-underdosed regions, and can compromise the capability of IMRT to deliver highly target-conformal dose distributions. This organ motion can in principle have a more detrimental effect on IMRT than on 3D conformal radiotherapy (3D-CRT). Indeed, the effect of motion on IMRT is a significant factor limiting the widespread use of thoracic IMRT. The literature reports that have quantified the effect of motion during IMRT differ widely on both the magnitude and importance of the unplanned over-and-underdosed regions. The purpose of this seminar is to systematically study the characteristics of the different effects that motion can have in IMRT, and to estimate the magnitude of the effects. Motion always leads to a blurring of the dose distribution. This effect is similar to the blurring of the picture of a moving object if the exposure time is too long. In its simplest form, the blurring can be understood by assuming that the treatment produces a static "dose cloud", and the tumor and the inner organs move within this static "dose cloud". As a result, sharp edges in the dose distribution will be blurred. In reality, the "dose cloud" is not static. First, at interfaces between structures of different densities and/or atomic numbers, there are interface phenomena that affect the dose distribution locally and loco-regionally. These interface effects move with the moving interfaces and thereby lead to a deformation of the spatial dose distribution. Secondly, the dose distribution also varies with time. In IMRT, each field is delivered as a succession of sub-fields or segments. The time dependence of the delivery and the organ position can lead to significant interplay or interference effects in a single treatment fraction. However, various studies have shown that the effect averages out after a typical number (30-40) of treatment fractions, and the remaining effect is typically reduced to less than 1% dose error (one standard deviation). Having that said, it should be kept in mind that with a 1% standard deviation the error will be bigger than 2% in a significant fraction of the voxels (5%). The interplay effect is specific to IMRT but appears to be small when the treatment is delivered in a typical fractionation scheme. Because in IMRT there is a tendency to reduce or compromise target margins, the blurring has potentially a bigger effect on the outcome of IMRT, unless precision dose delivery techniques (such as gated or motion-synchronized beams) are used. An alternative to the use of margins is to do the planning based on blurred dose distributions. This session will describe how the interplay of the target motion and IMRT delivery system results in delivery errors. The published literature on this issue will be critically examined. Different IMRT delivery systems, including compensators, SMLC, DMLC, helical and serial tomotherapy and protons, will be compared for their susceptibility to dosimetric delivery errors due to target and normal tissue motion. Methods that alleviate the effect of motion will also be discussed.

The educational objectives of this session include:

- (1) Understand the interplay between motion and IMRT delivery and how delivery errors can occur.
- (2) Distinguish between IMRT-specific motion effects and general motion effects.
- (3) Appreciate the similarities and motion effect differences between different IMRT delivery systems and conventional delivery.
- (4) Determine how to quantify IMRT motion effect errors.
- (5) To give an estimate of the magnitude of the effects both in single and multiple fractions.
- (6) Understand methods to alleviate IMRT motion effect errors.