

The CyberKnife® (Accuray, Inc., Sunnyvale, CA, USA) allows the delivery of robotic stereotactic radiosurgical treatments with a total clinical accuracy of less than a millimeter for stationary targets, and less than three millimeters for targets undergoing intra-fraction excursion. The system consists of a six-jointed robot (KUKA Roboter, Augsburg, DE), a compact 6 MV 9.5 GHz X-band linear accelerator as an end effector, a treatment couch capable of motion in five degrees of freedom (three translational, roll, pitch, but manual yaw), two ceiling-mounted kV x-ray sources, two amorphous silicon detectors, and various subsystems. The introduction of the RoboCouch® (Accuray, Inc.) has provided a patient support assembly capable of motion in six degrees of freedom.

Treatment planning is performed using MultiPlan® (Accuray, Inc.), a proprietary treatment planning system that has undergone much revision in the past few years. Treatment plans typically involve the delivery of 100-200 beams, using 1-3 fixed circular collimators, which range in size from 5-60 millimeters; however, it should be noted that some CyberKnife centers have upgraded to an iris variable collimator, thus obviating the need to change the collimators during treatment. Beams are delivered from fixed points in space called nodes. Node sets are arranged in either spherical (for intracranial treatments) or ellipsoidal (for extracranial treatments) configurations. The nominal SAD is fixed at 800 mm for intracranial treatments, and ranges from 900 mm to 1000 mm for body treatments. Treatment planning consists of the generation of candidate beams via targeting of the planning target volume (PTV) using random point placement within the PTV contour set, beam reduction and beam weight optimization through inverse planning, and plan evaluation of the resulting isodose distribution and dose-volume histograms (DVHs).

Dose calculation was implemented in early versions of MultiPlan® with simple ray tracing without contour correction, but subsequent releases have added contour correction as well as a parallel Monte Carlo engine. A simplex linear programming algorithm was the early preferred method of performing beam weight optimization, and an iterative algorithm introduced in later versions of the treatment planning software provided a second option, but it remains underdeveloped. The most current version of MultiPlan® features a completely redesigned inverse planning algorithm, which implements sequential multi-objective optimization. At no point in development has the ability to apply dose-volume constraints to critical organs been implemented. Instead, the user can only specify maximum doses to critical organs, or, in the latest version, the allowed mean doses to critical organs.

Treatment planning strategies usually involve the creation of tuning structures to shape the isodose distribution, with the addition of manual constraint points to address unwanted bleeding of the isodoses. Typical CyberKnife® SBRT sites are prostate, lung, pancreas, and spine.

Educational Objectives:

1. Understand the CyberKnife® treatment delivery system.
2. Understand the MultiPlan® treatment planning system and its limitations.
3. Understand the basic approach to treatment planning for CyberKnife® cases.