History of LINAC Radiosurgery

Since the first Radiosurgery treatment in 1951 Dr. Leksell continued searching for the best approach to perform his radiosurgery through trials and error, using the Proton Beam in Uppsala, Sweden and a linear accelerator (LINAC) before finally settling for Cobalt 60 photon beams. He concluded that the gamma ray was the most practical energy for Radiosurgery in a hospital setting. The Gamma Knife was born. During those years, a patient was treated in London with conventional radiation therapy using a LINAC in 1953, while in the United States a 2-year-old boy received treatment for an eye tumor with a LINAC in 1953. The first Gamma Knife was inaugurated in Sweden in 1968, slowly spreading around the world as the instrument of choice for Radiosurgery.

LINACs gained the place in medicine as the prime approach to treat oncological patients with radiation. By 2006, more than 40 million cancer patients had already been treated with the LINAC technology. It took 30 years after the first patient was treated with a LINAC, the Radiosurgery proof of concept with the Gamma Knife, rotation of Cobalt-60 sources in Spain by Barcia-Salorio in 1981, particle beams at Berkeley and Harvard Universities in the United States for an Argentinean neurosurgeon, Betty in collaboration with Derichinsky take advantage of the versatility and cost-effectiveness of the LINAC, adapting it to Radiosurgery in 1983.

While working in France, Betti and Derechinsky [1983] aligned the head of a patient in different angles in relation to the beam line of a LINAC to treat an AVM. They gained a place in history as the first physicians to perform Radiosurgery using the linear accelerator approach.

Heifetz in 1984 promptly followed their idea in Los Angles, USA. In Italy and Germany two important reports appeared describing LINAC adaptations for radiosurgery by Colombo et al in 1985 and Hartman et al 1985, respectively. These three LINAC Radiosurgery reports set the stage for the development of this versatile technique. Winston and Lutz in 1988, working in Boston, developed the methodic steps of quality assurance for precision LINAC Radiosurgery. The LINAC approach was heavily criticized due to imprecision of the machine in its rotation axis in comparison to the Gamma Knife, established as the gold standard technique of precision in the field.

LINACs were not designed for high precision Radiosurgery, since the Radiation Oncologists over the years relied on radiobiological differential response to minute fractions of radiation to decrease complications. As specialists in cancer, a diffuse disease, they needed a technique that could give good margins of radiation to contain tumor spread. When Neurosurgeons tried to apply the linear accelerator beam to ablate lesions with highly concentrated dose, the precision of beam delivery became a limiting factor.

The issue of precision was initially resolved with the description of a gantry correction device by two University of Florida scientists, Friedman and Bova in 1989. They brought the first LINAC commercial solution to the world market. Lately a LINAC dedicated to Radiosurgery was constructed under the orientation of Kooy et al 1996. This allowed LINAC Radiosurgery to become widely spread. A few groups committed to high precision radiosurgery used the technique in functional disorders of the brain, for example for treatment of trigeminal neuralgia, tremor and pain, especially De Salles et al. and Friedman et al. at the University of California Los Angeles and University of Florida, respectively. LINAC Radiosurgery became a versatile technique, however requiring an extremely dedicated and committed team to precision. This is difficult to achieve in services using the LINAC for large number of patients per day with fractionated treatments, as it occurs in general Radiation Oncology departments. It does allow however the application of Radiosurgery to the spine and other sites in the body. An approach using a miniature LINAC attached to a robot emerged at Stanford University in the early 1990's under the leadership of the Neurosurgeon John Adler. This approach is gaining popularity, mostly because of its ability to reach the whole body, its design for Radiosurgery and for its frameless capability. The introduction of cone beam CT and other sophisticated image guidance systems had improved the repositioning in case of staged radiosurgery: these developments allow for real time updated imaging during the treatment to guarantee the patient's positional accuracy. This spearheaded the hypofraction movement in extra cerebral tumors such as lung, liver prostate tumors. This has been changing the practice of radiation therapy and neurosurgery. The increase interest in Linac radiosurgery for brain and extracerebral lesions has been also confirmed by the incredible number of peer reviewed publications in the last 5 years.

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