2.5 External Stereotactic Focal Irradiation
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1 Introduction

"Radiosurgery" is a somewhat provocative term for a special concept of radiotherapy (LEKSELL 1951). It describes a percutaneous, stereotactically guided irradiation delivering a single high dose with collimated narrow beams. The precise stereotactic localization of the target point and a steep dose gradient outside the target volume allow the administration of high doses to a lesion without damage of adjacent normal tissue.

Units for radiosurgery were designed at Stockholm using multiple external cobalt-60 $\gamma$-sources, at Boston operating with a high-energy proton beam of a cyclotron, and at Berkeley operating with helium ions accelerated by a synchrocyclotron (STEINER 1986; KJELLBERG et al. 1983a, b; FABRIKANT et al. 1984).

An attractive alternative to these complicated and expensive facilities is to modify a conventional linear accelerator for the purpose of radiosurgery. At the present time numerous therapy groups have developed or are developing radiosurgery units associated with commercial linear accelerators in a special moving field arrangement, as in Vincenza, Montreal, Buenos Aires, and Boston (COLOMBO et al. 1986; PODGORSAK et al. 1988; BETTI et al. 1983; LUTZ et al. 1988). At the German Cancer Research Center in Heidelberg such a system was started in 1982/1983 and has been available for the treatment of patients since then (HARTMANN et al. 1985; STURM et al. 1987; ENGENHART et al. 1989).

Classic indications for radiosurgery are cerebral arteriovenous malformations (AVMs) and benign, radioresistant, primary tumors of the brain. We have extended the indication to solitary brain metastases of radioresistant primary tumors (STURM et al. 1987). This review will concentrate on the technical aspects of stereotactic irradiation and on the treatment of brain metastases and arteriovenous malformations.

2 Irradiation Technique and Planning

For stereotactic, single, high-dose irradiation we use a system containing three components (HARTMANN et al. 1985): (a) a modified linear accelerator (Mevatron 77, Siemens AG, FRG), (b) a stereotactic localization and target positioning system (Fischer, FRG), and (c) a 3-dimensional planning system (SCHLEGEL et al. 1984).

Irradiation is carried out with a series of moving fields in noncoplanar plans. After every gantry motion the treatment table with the patient rotates to another position (Fig. 1). Additional circular tungsten collimators reduce the penumbra and permit adaptation to diverse field diameters. The superposition of the irradiation fields delivers spherical dose distributions with steep dose gradients outside the target volume (7–15%/mm) comparable with the profiles of cobalt-60 units or 185-MeV protons used for radiosurgery (Fig. 2).

The stereotactic localization system consists of a Riechert-Mundinger head frame modified with a measuring phantom for artifact-free use in a computerized tomography (CT) scanner (STURM et
al. 1983). Plexiglass squares with embedded steel wires allow direct measurement of the target point coordinates from the CT scan. A corresponding positioning system allows adjustment of the target point to the isocenter of the irradiation facility with stereotactic precision. Essential for this irradiation technique is an exact control of the different moving parts: the central beam of the irradiation field, the axis of the patient table, and the axis of the gantry have to meet precisely in one point: the isocenter.

An alternative system for patient fixation consists of an individual light cast mask, which can be attached to the CT scanner couch and the linear accelerator couch by a wooden-based stereotactic frame. This mask system is less accurate than the stereotactic head frame attached to the patient's skull; nevertheless, the accuracy of reproducibility is relatively high, with a mean deviation of ±1 mm and a maximum deviation of ±2 mm.

Computer programs have been developed for 3-dimensional treatment planning (Fig. 3). Field

Fig. 1. Schematic illustration of gantry and patient's couch rotation around the isocenter during stereotactic focal irradiation

Fig. 2. Dose profiles of collimated narrow beams. Left, the 9, 21, and 26 mm beams from the linear accelerator using the described moving field technique; right, beams of other irradiation units for radiosurgery