Medical Dosimetry ■■ (2018) ■■–■■

Medical Dosimetry

journal homepage: www.meddos.org

Dosimetry Contribution:

3-D treatment planning system—Leksell Gamma Knife treatment planning system

Fanqing Guo, PhD

Department of Therapeutic Radiology, Yale School of Medicine, New Haven, CT 06520-8040

ARTICLE INFO

Article history:
Received 21 February 2018
Accepted 5 March 2018

Keywords:
Stereotactic radiosurgery
SRS
Brain metastases
Leksell Gamma Knife
Leksell Gamma Plan
Treatment planning system
TPS

ABSTRACT

Leksell Gamma Plan (LGP), the treatment planning system for the Leksell Gamma Knife (LGK) stereotactic radiosurgery, has evolved from the primitive KULA system to the present-day powerful version of image-guided stereotactic radiosurgery. Through many years of development, LGP has improved on its dose calculation accuracy, speed, and user interface. This allows more accurate irradiation of the target while sparing the nearby normal tissues and critical structures better.

Introduction

Among many gamma knife systems, Leksell Gamma Knife (LGK) is a radiation treatment unit specifically designed for intracranial radiosurgery. Originally developed by Lars Leksell in Stockholm, Sweden, the unit uses radioactive Cobalt-60 as radiation sources. The gamma rays from around 200 Cobalt-60 sources, with specially designed spatial pattern, focus on a precise spot 3-dimensionally. Together with the stereotactic frame coordinate system and treatment planning system, the radiation can be accurately delivered to the target while sparing the normal tissues and critical structures to the maximum extent. LGK has evolved from the original models LGK U, LGK B, LGK C, LGK 4, and LGK 4C, to models Perfexion and Icon. Currently, models 4C, Perfexion, and Icon are actively used clinically, with Perfexion as the mainstream model. This review will focus on the treatment planning system for LGK, Leksell Gamma Plan (LGP) version 11, with Perfexion as the model. For early models, the reader can refer to the literature.[1,2]

Indications for LGK radiosurgery treatment include virtually all types of intracranial malignant tumors, benign tumors, vascular disorders, as well as functional disorders and psychiatric disorders. Malignant tumors include brain metastases, glial tumors, and so on. Benign tumors include meningioma, vestibular schwannoma, pituitary adenoma, and so on. Vascular disorders include arteriovenous malformation. Functional disorders include trigeminal neuralgia and psychiatric disorders such as obsessive compulsive disorder. Criteria for Gamma Knife radiosurgery include (1) tumors up to 3 to 4 cm, (2) targets 2 mm or more away from optical apparatus, and (3) patient's cooperation for

Reprint requests to Fanqing Guo, PhD, Department of Therapeutic Radiology, Yale School of Medicine, P.O.Box 208040, New Haven, CT 06420-8040.

E-mail: fanqing.guo@yale.edu

https://doi.org/10.1016/j.meddos.2018.03.001

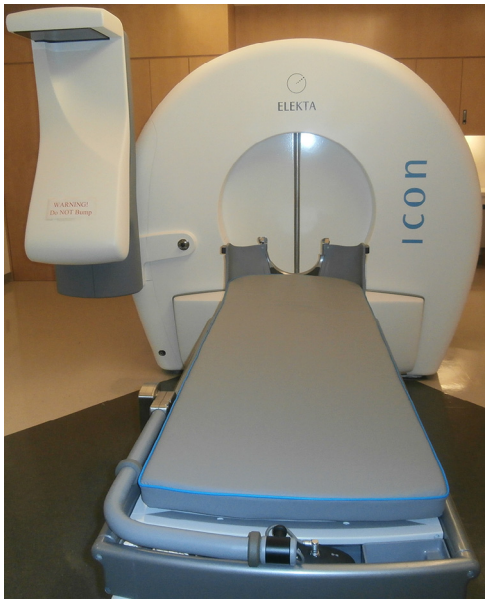

Fig. 1. An LGK Icon unit just upgraded from Perfexion. (Color version of figure is available online.)

taking magnetic resonance imaging or computed tomography images.[3]

Methods and Materials

The LGP is compatible with 6 types of LGK systems, from the newest to the oldest, which are LGK Icon, LGK Perfexion, LGK 4C, LGK 4, LGK C, and LGK B models. The most currently used model is LGK Perfexion, which uses 192 Cobalt-60 sources. Each source has initial activity around 30 Ci so the total initial activity is about 6000 Ci. The half-life of Cobalt-60 is 5.272 years. Cobalt-60 decays via beta decay to Nickel-60, emitting 2 monoenergetic gamma rays, 1.17 and 1.33 MeV, with an average energy of 1.25 MeV. Percent depth dose of the gamma rays is similar to 4 MV photons generated by linear accelerators. In the United States, the Nuclear Regulatory Commission regulates its medical use. Figure 1 shows a typical LGK Perfexion unit, which was just upgraded to LGK Icon system recently.

LGP version 11.0 is the latest treatment planning system for LGK stereotactic radiosurgery. It was developed on a Linux-based CentOS operating system with adaptions especially for treatment planning application. LGP takes tomographic and projectional images for the simulation and planning of stereotactic radiosurgery. Tomographic images such as computed tomography, magnetic resonance imaging, and positron emission tomography scanners can be used, as well as projectional images from angiograms. Digital images can be imported into the system via the computer network as well as other media such as CD and DVD. The LGP system can plan beams—shots—on a single target or multiple targets. The basic steps of treatment planning are (1) defining the cranial target or targets, (2) selecting the collimators to be used during treatment, and (3) determining the parameters, that is, location, beam on time, and gamma angle, of the radiation shots to be delivered by LGK (Table 1).

Table 1
Brief history of Leksell Gamma Knife systems[1,3-6]

1949	Idea of noninvasive brain surgery conceived by Dr. Lars Leksell
1950s	Experiment with proton beam and linear accelerator by Dr. Lars Leksell
1968	First Model U LGK installed at the Karolinska Institute in Stockholm
1986	First Model U LGK installed at the University of Pittsburgh
~1995	Model B LGK developed along with GammaPlan software
1999 to 2002	Model C, 4, and 4C LGK and Automatic positioning system introduced
2006	LGK Perfexion system introduced
2016	LGK Icon introduced

The typical workflow for treatment planning for LGK Perfexion or Icon follows these steps per LGP Online Reference Manual,[7] as shown in Table 2. They can be generally divided into 3 parts: (A) patient and treatment preparations, which include steps 1 to 8, (B) target definition, shot placement, and dose calculation, which include steps 9 to 13, and (C) final plan approving and exporting for treatment. Part B may be iterated for different treatment targets until all targets are covered with ideal dose distribution. Figure 2 shows an LGP treatment planning application screen with a workspace and an open dialog. It is very important

Table 2
A typical workflow for treatment planning for LGK Perfexion or Icon per LGP Online Reference Manual[7]

1	Start with creation of a new patient or a new examination of an existing patient.
2	Import image set(s).
3	Choose fixation configuration.
4	Provide frame cap information and/or detailed coordinate frame measurements if Leksell Coordinate Frame G is used.
5	Define stereotactic reference based on fiducials or a CBCT study.
6	Specify the skull shape.
7	Specify target volume(s).
8	Specify any risk zone(s) close to a lesion.
9	Specify target(s).
10	Place shot(s) for target(s).
11	Protect risk zone(s) using Dynamic Shaping tool.
12	Adjust the dynamically shaped dose distribution as needed.
13	Review the clearance status of the shot(s).
14	Approve the treatment plan.
15	Print the treatment plan.
16	Sign the printed treatment plan.
17	Export the treatment plan to Leksell Gamma Knife console.

CBCT, cone beam computed tomography.