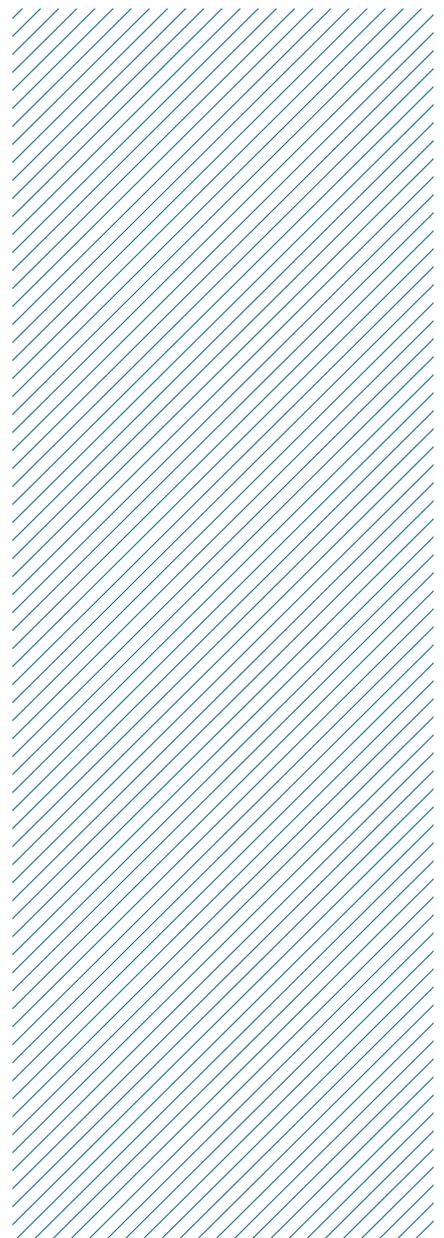


White Paper

Automatic positional delivery correction using a stereotactic CBCT in Leksell Gamma Knife[®] Icon[™]



Introduction

The Leksell Gamma Knife® Icon™ system, with a stereotactic Cone Beam CT (CBCT), enables increased workflow flexibility and additional treatment options—e.g., planning on frameless images and delivering fractionated frameless treatments. In an image guided workflow the stereotactic reference for the plan is defined by the CBCT images taken prior to start of treatment.¹ Co-registration of the planning images with reconstructed CBCT images² at the time of treatment gives a geometric transformation that is used to correct the delivery of the plan according to the current patient position.

Automatic correction

For relocatable mask immobilization, the delivery of the plan is automatically corrected, according to the actual patient position from stereotactic Cone Beam CT images taken at the time of treatment, without any mechanical rotations of the patient.

The correction is done so the delivery of the plan preserves the planned position of each individual isocenter (shot) in the patient anatomy according to the current patient position. The rigid transformation is based on the co-registration of the planning and reconstructed CBCT images. It describes the translation and rotation of the patient, and is used to accomplish the correction of each shot. The delivery characteristics, i.e., beam-on times and collimators, are otherwise identical to the plan.

Dosimetrical implications

The dosimetrical implications of the correction can be understood by looking at the unique beam geometry configuration of Leksell Gamma Knife® Icon™ (see Figure 1). In a single isocenter (shot), 192 non-coplanar pencil beams surrounding the patient form a small volume of highly intense radiation within the target.³ As more isocenters (shots) are added to cover the target, more beams contribute to the target dose, while beams for each shot further away from the target are spread out over a large volume and do not overlap.

For points in the target and its proximity, beams from many different angles contribute to the dose. After rotation, some of those beams will travel a longer

distance through the anatomy and some beams a shorter distance compared to the original plan. Because of this, averaging the net effect on the dose distribution is very small at high dose levels.

For positions further away from the target there are fewer beams significantly contributing to the dose in any given point, and they are likely to come from similar directions, implying that they either propagate a consistently longer—or shorter—distance through the anatomy compared to the planned dose. This causes a net effect on the dose distribution which can be seen locally for the lower isodoses. However, global measures, e.g., volume of an isodose, are only very little affected.

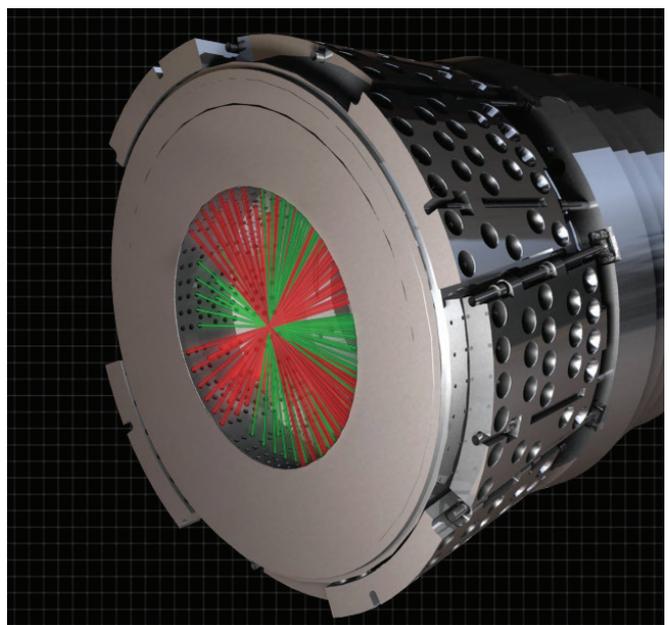


Figure 1. Beam geometry of Leksell Gamma Knife® Icon™

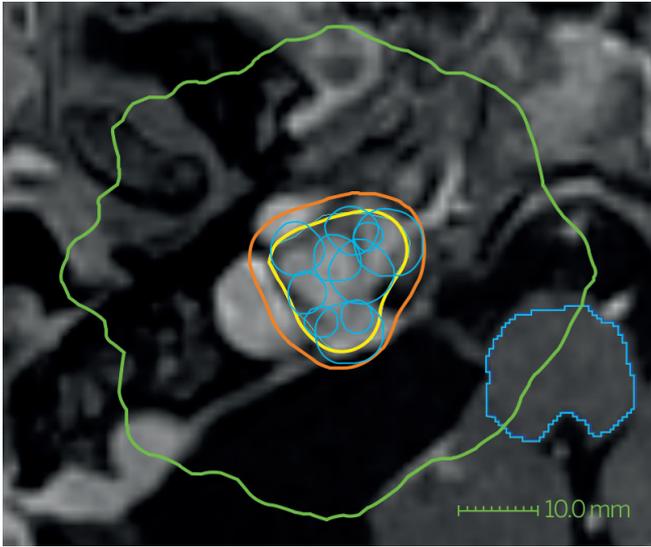


Figure 2.
Original plan. The target volume with individual shots outlined.

To illustrate the effect of delivery correction, an image slice of an original plan is shown in Figure 2. A target is planned at 12Gy (in yellow) with several isocenters (seen in the figure), and two lower isodoses are also shown (1Gy in green; 8Gy in orange).

In Figure 3, the head is rotated five degrees around the z-axis (orthogonal to the image slice). Both the planned dose (dotted line) and the corrected delivery dose (solid line) are shown.

Note that, due to the correction, the isocenter positions are invariant relative to the anatomy. Apparently, the higher isodoses are almost unchanged, as seen for the 12Gy and 8Gy isodose lines, implying that a very good coverage and selectivity is maintained. At low isodoses the effect is larger, with the 1Gy isodose being somewhat different compared to the original 1Gy isodose, but the volume covered is almost the same. These results are consistent with the analysis presented in the previous section.

Leksell GammaPlan[®] provides tools for comparing the corrected delivery dose with the planned dose, using both image views. It also shows dose volume histograms for both the original and corrected delivery, see Figure 4.

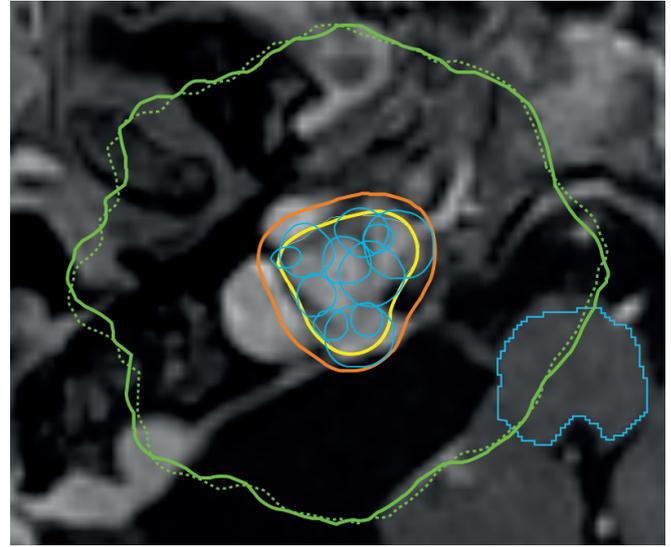


Figure 3.
Rotation 5 degrees about the z-axis.

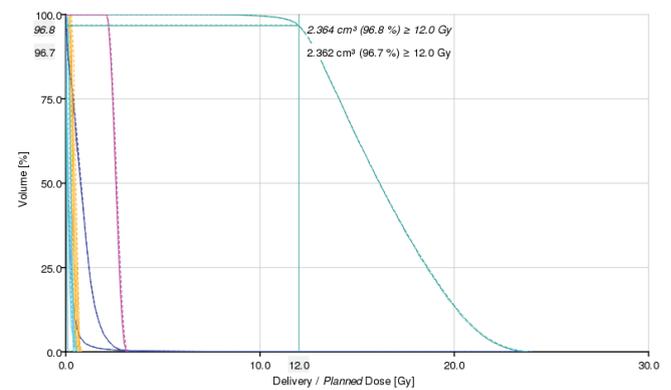
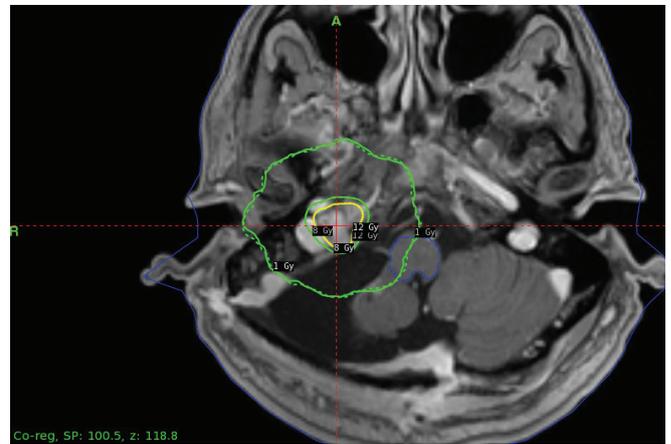


Figure 4.
Dose volume histograms for original and corrected delivery.

1. Design and performance characteristics of a Cone Beam CT system for Leksell Gamma Knife Icon, White Paper, 1509394.02
2. Accuracy of co-registration of planning images with Cone Beam CT images, White Paper, 1509393.02
3. Lindquist C, Paddick I. The Leksell Gamma Knife Perfexion and comparisons with its predecessors, Neurosurgery 2007 Sep;61(3 Suppl):130-40; discussion 140-1.



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Elekta Offices

Elekta AB

Box 7593
SE-103 93
Stockholm, Sweden

T +46 8 587 254 00
F +46 8 587 255 00

Europe

T +46 8 587 254 00
F +46 8 587 255 00

Turkey, India, Middle East & Africa

T +90 216 474 3500
F +90 216 474 3406

North & Central America including the Caribbean

T +1 770 300 9725
F +1 770 448 6338

South America & Cuba

T +55 11 5054 4550
F +55 11 5054 4568

Asia Pacific

T +852 2891 2208
F +852 2575 7133

Japan

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