GEOMETRIC, DVH AND PLAN QUALITY DIFFERENCES INDUCED FROM DIFFERENT PATIENT IMAGE REGISTRATION METHODS USED IN GAMMA KNIFE APPLICATIONS

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Purpose - Introduction

Stereotactic radiosurgery

- Small target volumes, steep dose gradients, need for geometrical accuracy better than 1 mm

Leksell Gamma Knife (LGK)

- Excellent mechanic accuracy. However the efficiency of the technique is related to the precision of contouring.
- Geometric uncertainties in the determination of targets and organs at risks (OARs) in the 3-dimensional (3D) Leksell space may deteriorate LGK efficiency
- Image registration is performed either using the fiducial markers generated in the MR images by the N-shaped rods on the Leksell MR localization or through anatomical-based co-registration to corresponding registered (using the fiducial markers) CT images.
- Spatial inaccuracies of the order of 1 mm may have a significant dosimetric impact due to the steep dose gradient that LGK dose distributions exhibit in all three dimensions

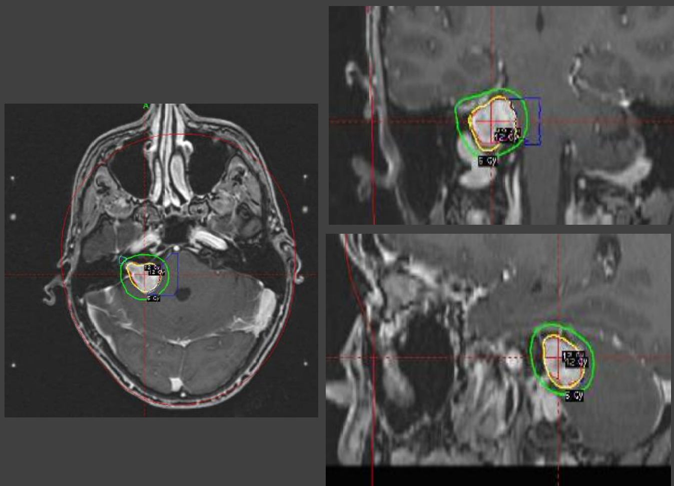
Scope :

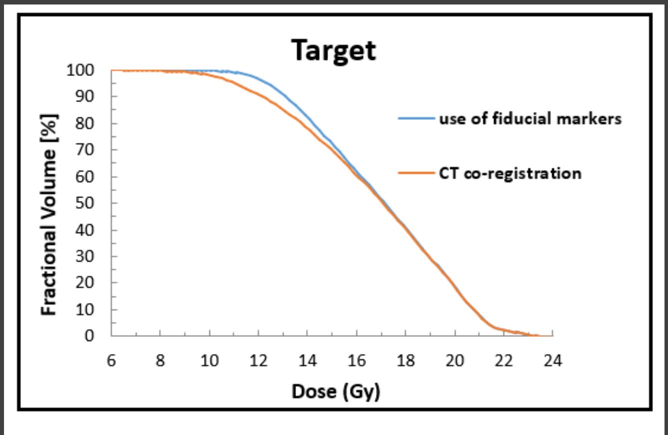
This work compares the two different methods used in GK radiosurgery for MR image registration and assess geometric differences and differences induced in plan quality and DVH-indices clinically used for plan evaluation and acceptance.

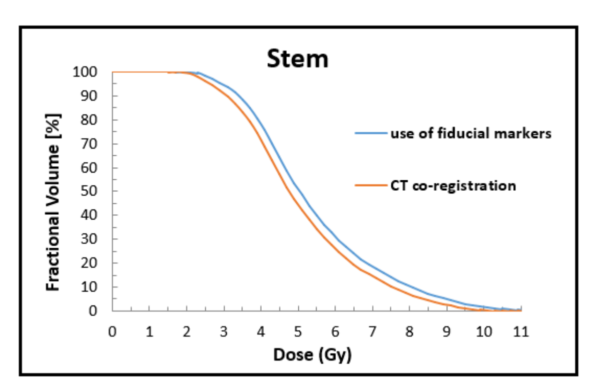
Materials & Methods

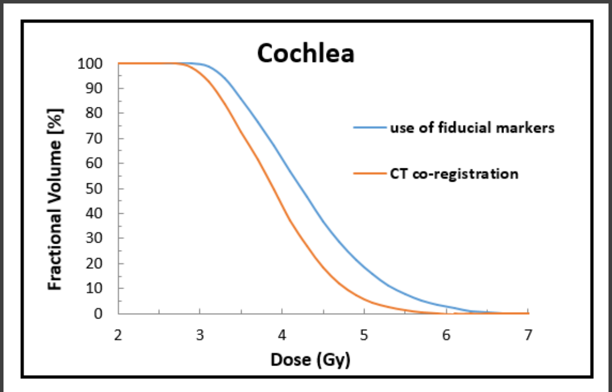
- A plan cohort formed by patients with acoustic neuroma, pituitary adenoma or meningioma treated with gamma knife radiosurgery was used
- Patient images, structures and dose grid (resolution down to 0.1 x 0.1 x 0.1 mm^3), derived using the two different registration methods were exported using the DICOM-RT feature of gamma plan.
- Data were anonymized and imported to an independent free/open source software package (3D slicer) for dose distribution and DVH analysis.
- DVH and plan quality indices clinically used for plan evaluation and acceptance for target (D95%, TV_{PIV}) and critical organs (Dmax, Dmean, , $D_{0.003cc}$ $D_{0.03cc}$) were determined and compared for the two different registration methods .

Results : Acoustic neuromas (I)









DVH for the target and critical organs (brain stem and cochlea) for the two different methods used in GK radiosurgery for a typical acoustic neuroma plan with a target volume (TV) of 3cc.

Results : Acoustic neuromas (II)

$\overline{\Delta x}$ (mm)	$\overline{\Delta y}$ (mm)	$\overline{\Delta z}$ (mm)	$\overline{\Delta r}$ (mm)
0,414	0,301	0,238	0,613
σ_x (mm)	σ_y (mm)	σ_z (mm)	σ_r (mm)
0,130	0,302	0,132	0,247

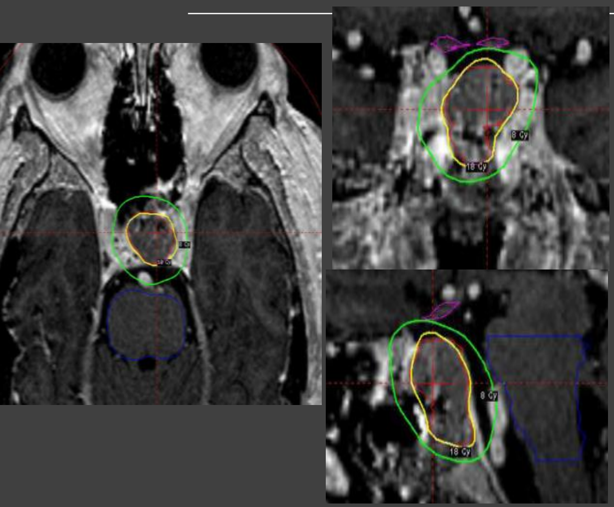
TARGET	
$\overline{\%\lvert\Delta D95\%\rvert}$	$\overline{\%\lvert\Delta Dmean\rvert}$
5,629	1,319
$\sigma_{\Delta D95\%}$(%)	$\sigma_{\Delta Dmean}$(%)
5,501	1,820

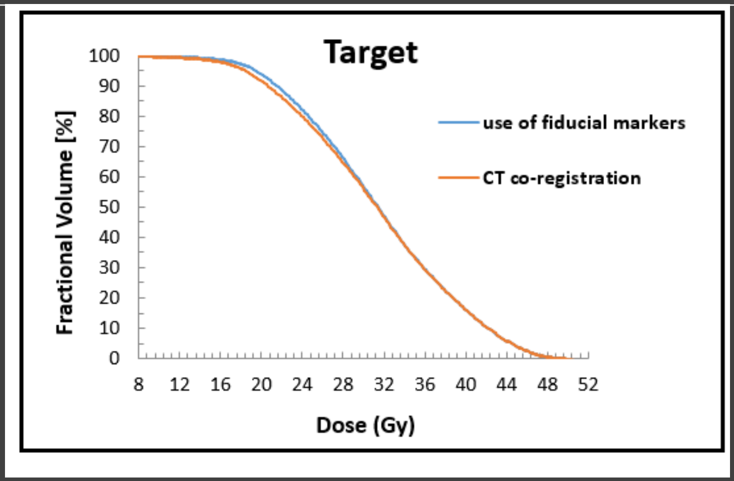
STEM		
$\overline{\%\lvert\Delta Dmean\rvert}$	$\overline{\%\lvert\Delta Dmax\rvert}$	$\overline{\%\lvert\Delta D0,003cc\rvert}$
3,803	4,313	5,313
$\sigma_{\Delta Dmean}$ (%)	$\sigma_{\Delta Dmax}$ (%)	$\sigma_{\Delta D0.003cc}$ (%)
2,497	3,287	4,735

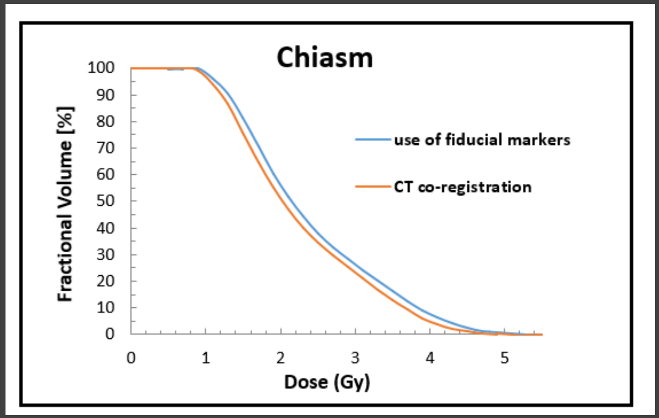
COCHLEA		
$\overline{\%\lvert\Delta Dmean\rvert}$	$\overline{\%\lvert\Delta Dmax\rvert}$	$\overline{\%\lvert\Delta D0,003cc\rvert}$
5,468	7,548	6,646
$\sigma_{\Delta Dmean}$ (%)	$\sigma_{\Delta Dmax}$ (%)	$\sigma_{\Delta D0.003cc}$ (%)
4,134	4,978	5,466

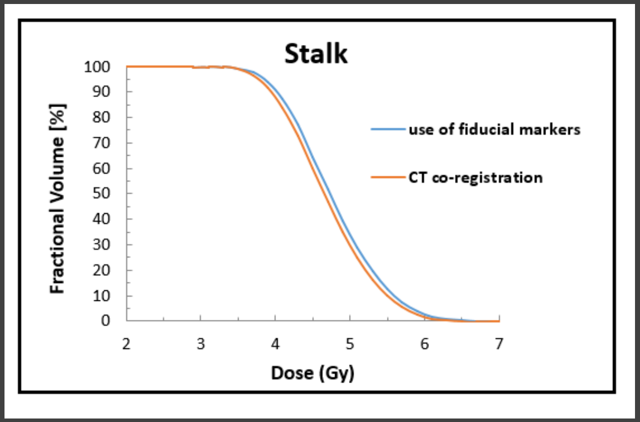
Geometric differences and differences of target and critical organs DVH indices used for plan evaluation and acceptance (mean and standard deviations) between the two different registration methods, for 10 acoustic neuroma patient plans

Results : Pituitary Adenomas (I)









DVH for the target and critical organs (chiasma and stalk) for the two different methods used in GK radiosurgery for a typical pituitary adenoma plan with a target volume (TV) of 4cc.

Results : Pituitary Adenomas (II)

$\overline{\Delta x}$ (mm)	$\overline{\Delta y}$ (mm)	$\overline{\Delta z}$ (mm)	$\overline{\Delta r}$ (mm)
0,301	0,627	0,704	1,063
σ_x (mm)	σ_y (mm)	σ_z (mm)	σ_r (mm)
0,187	0,309	0,370	0,314

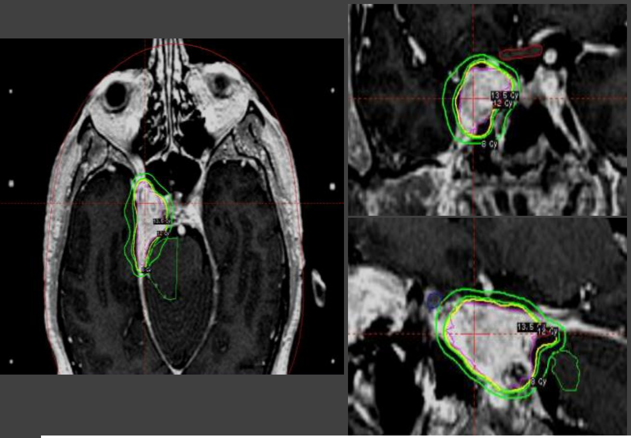
TARGET	
$\overline{\%\lvert\Delta D95\%\rvert}$	$\overline{\%\lvert\Delta Dmean\rvert}$
9,704	1,702
$\sigma_{\Delta D95\%}$(%)	$\sigma_{\Delta Dmean}$(%)
5,765	1,073

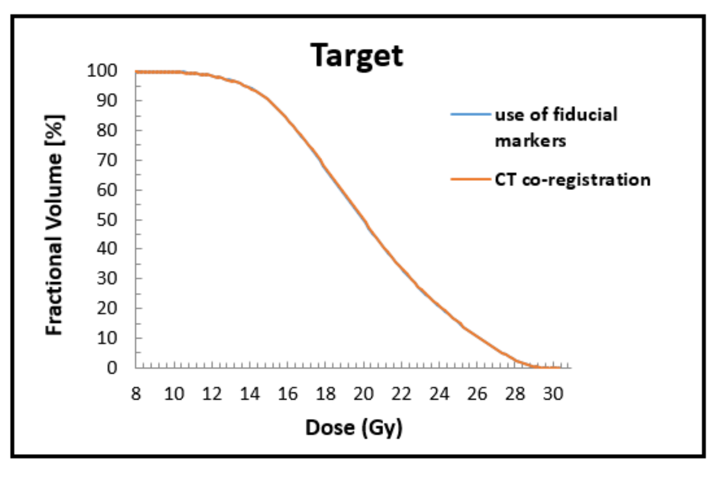
CHIASM		
$\overline{\%\lvert\Delta Dmean\rvert}$	$\overline{\%\lvert\Delta Dmax\rvert}$	$\overline{\%\lvert\Delta D0,003cc\rvert}$
8,399	9,714	8,870
$\sigma_{\Delta Dmean}$ (%)	$\sigma_{\Delta Dmax}$ (%)	$\sigma_{\Delta D0.003cc}$ (%)
6,045	8,446	7,678

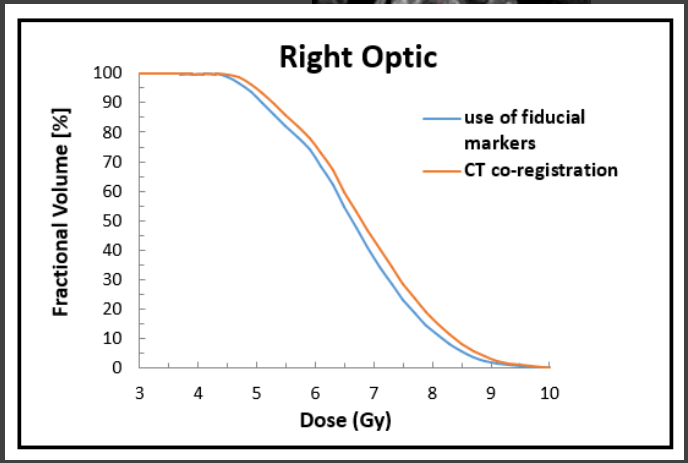
STALK		
$\overline{\%\lvert\Delta Dmean\rvert}$	$\overline{\%\lvert\Delta Dmax\rvert}$	$\overline{\%\lvert\Delta D0,003cc\rvert}$
7,604	9,885	8,011
$\sigma_{\Delta Dmean}$ (%)	$\sigma_{\Delta Dmax}$ (%)	$\sigma_{\Delta D0.003cc}$ (%)
5,514	9,808	6,239

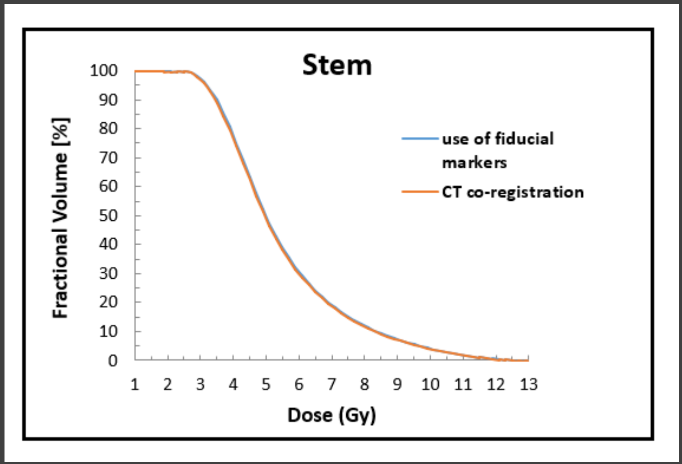
Geometric differences and differences of target and critical organs DVH indices used for plan evaluation and acceptance (mean and standard deviations) between the two different registration methods, for pituitary adenoma patient plans

Results : Meningiomas (I)









DVH for the target and critical organs (right optic nerve and stem) for the two different methods used in GK radiosurgery for a typical meningioma plan with a target volume (TV) of 6 cc.

Results : Meningiomas (II)

$\overline{\Delta x}$ (mm)	$\overline{\Delta y}$ (mm)	$\overline{\Delta z}$ (mm)	$\overline{\Delta r}$ (mm)
0,323	0,365	0,530	0,760
σ_x (mm)	σ_y (mm)	σ_z (mm)	σ_r (mm)
0,083	0,383	0,104	0,274

TARGET	
$\overline{\%\lvert\Delta D95\%\rvert}$	$\overline{\%\lvert\Delta Dmean\rvert}$
1,826	0,486
$\sigma_{\Delta D95\%}$(%)	$\sigma_{\Delta Dmean}$(%)
2,178	0,449

OPTIC NERV		
$\overline{\%\lvert\Delta Dmean\rvert}$	$\overline{\%\lvert\Delta Dmax\rvert}$	$\overline{\%\lvert\Delta D0,003cc\rvert}$
2,851	2,902	2,661
$\sigma_{\Delta Dmean}$ (%)	$\sigma_{\Delta Dmax}$ (%)	$\sigma_{\Delta D0.003cc}$ (%)
0,754	2,265	2,637

Geometric differences and differences of target and optic nerve DVH indices used for plan evaluation and acceptance (mean and standard deviations) between the two different registration methods, for meningioma patient plans

CONCLUSIONS

Geometric differences of the order of 1mm between the two different registration methods were observed.

These differences can considerably influence plan evaluation indices of both target and OARs leading to dose differences of the order of 10% in D95% values of target volume. Dose differences of similar degree were observed in D_{max} and $D_{0.003cc}$ values of OARs.

Despite being relatively small (of the order of 1mm), geometric differences between the two registration methods used in GK radiosurgery may affect considerably plan quality due to high dose gradients encountered in such applications.