DEFORMABLE IMAGE REGISTRATION FOR CT IMAGE SERIES OF THE THORAX REGION

S Sarudis[1,2], A Karlsson[1,3], D Bibac[4], J Nyman[5] and A Bäck[1,3]

[1]Department of Radiation Physics, Sahlgrenska Academy, University of Gothenburg, Sweden
[2]Department of Medical Physics, County Hospital Ryhov, Jönköping, Sweden
[3]Department of Therapeutic Radiation Physics, Sahlgrenska University Hospital, Gothenburg, Sweden
[4]Department of Diagnostic Imaging and Laboratory Medicine, Södra Älvsborgs Hospital, Borås, Sweden
[5]Department of Oncology, Sahlgrenska University Hospital, Gothenburg, Sweden

For additional information contact:
Sebastian Sarudis, sebastian.sarudis@vgregion.se

This research project has been funded by:
FUTURUM – Academy for health and care

Conclusion

Visually acceptable DIRs (DSC > 0.87) were achievable for moving structures with constant volume and shifts ≤ 30 mm in phantoms and shifts ≤ 16 mm in patients. Visually acceptable DIRs implied dose deviations ≤ 3.6 percentage units on patient CT image series of the thorax region.

Purpose

Evaluate the performance of three commercial deformable image registration (DIR) software solutions (RayDeformable, SmartAdapt and Velocity) for computed tomography (CT) image series of the thorax.

Method

Three DIR software solutions were evaluated by performing DIR on CT image series of a thorax phantom (CIRS 008A) with tumor inserts and on 4-dimensional CT image series of the thorax for six patients. For each DIR, the shape and position of the deformed structures and the corresponding structures in the target image series that the DIRs were set to reproduce, were compared for tumor shifts between 0–53 mm. Two quantitative measures were used, the center of mass shift (CMS) and the Dice similarity coefficient (DSC) as well as visual examination of the registered images. Dose calculations on the deformed patient image series were compared to calculations on the un-deformed target image series for the gross tumor volume (GTV) (D_{Mean} and $D_{98\%}$), lung (V_{20Gy},V_{12Gy}), heart ($D_{2\%}$) and spinal cord ($D_{2\%}$).

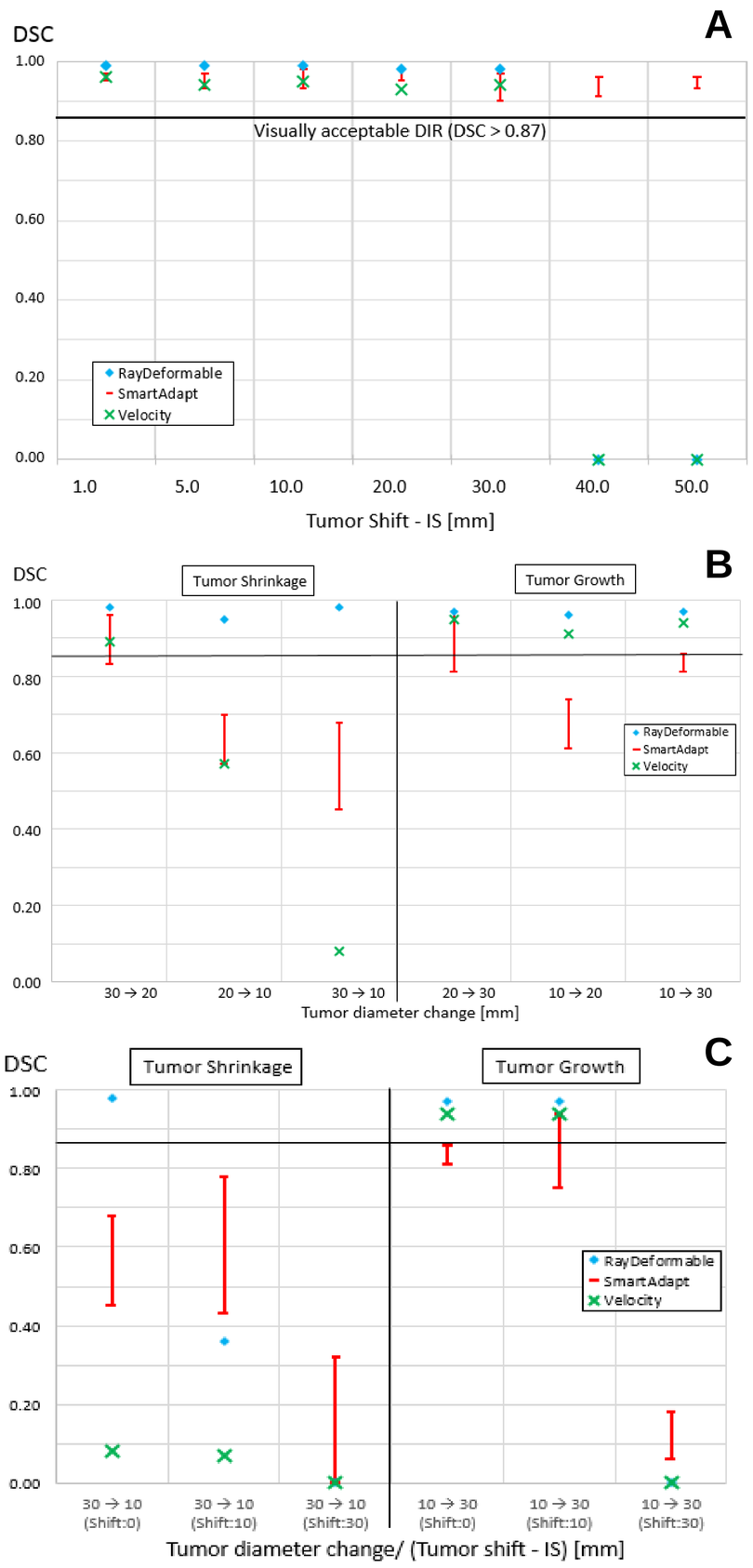

***Fig 1**. DSC for ten repetitive DIRs for (A) moving tumor with fixed volume of 14.1 cm³ (B) non-moving tumor with changing volume and (C) moving tumor with changing volume between the source and the target images. Diameter change X → Y indicates the change in tumor diameter in millimeters.*

Results

In the phantom, moving structures with constant volume and shifts ≤ 30 mm were reproduced with DSC ≥ 0.91 and CMS ≤ 0.9 mm by all the software (Fig 1A). For shifts > 30 mm two software failed. Deformations including volume changes (Fig 1B - 1C) were less accurate with 3/12 and 9/12 DIRs considered visually un-acceptable (corresponding to DSC ≤ 0.87) for the best and the worst software respectively. For patients, (Fig 2) the organs at risk were reproduced with DSC ≥ 0.83. GTV shifts of 7 and 16 mm (pat 4 & 5) were reproduced with DSC ≥ 0.88 by all the software. GTV shifts of 22 and 27 mm were reproduced with DSC ≥ 0.90 by two software while one of the software resulted in DSC ≤ 0.40 (pat 2 & 6). GTV shifts of 23 and 53 mm could not be reproduced by any of the software (pat 1 & 3). The obtained DSC varied between deformations with SmartAdapt (indicated as a red interval illustrating the maximum and minimum DSC in Fig 1 & 2) while Velocity and RayDeformable gave the same results for each repetition. Including both phantom and patient cases, the best and worst software succeeded in visually acceptable DIRs, for 18/25 and 12/25 cases respectively. Visually acceptable DIRs resulted in absorbed dose deviations in the evaluated dose parameters of ≤ 3.6 percentage units (Table 1).

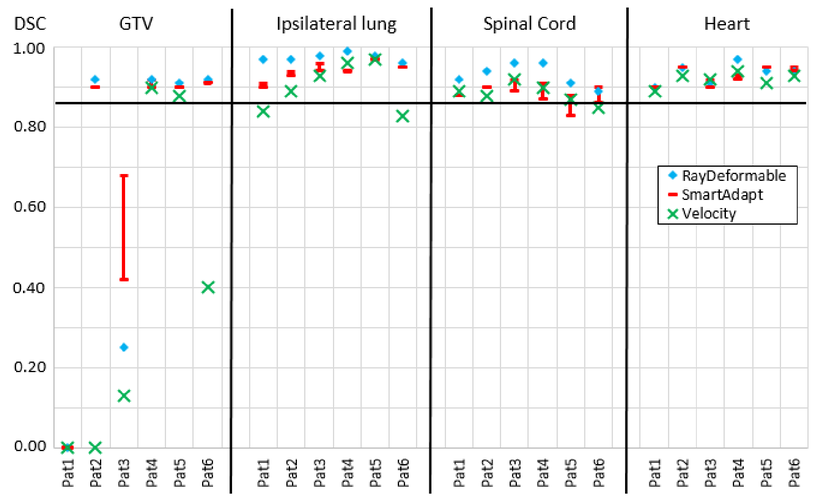

***Fig 2**. DSC for ten repetitive deformations performed on 4D-CT image series of patients with moving lung tumors.*

Patient #	Calculation CT	GTV		Ipsilateral lung		Spinal Cord	Heart
		$D_{98\%}$	D_{Mean}	V_{20Gy}	V_{12Gy}	$D_{2\%}$	$D_{2\%}$
1	RayDeformable	-5.5	8.7	1.0	2.9	0.9	1.2
	SmartAdapt	-9.3	0.7	1.1	3.6	1.3	1.3
	Velocity	0.0	12.7	2.5	4.7	1.3	1.3
2	RayDeformable	0.0	-0.3	-0.3	-0.3	0.2	0.3
	SmartAdapt	0.0	-2.0	-2.7	-3.0	0.7	1.3
	Velocity	-26.7	18.7	-0.3	-0.6	1.3	2.0
3	RayDeformable	-4.2	0.3	-0.1	-0.3	0.0	-0.1
	SmartAdapt	-7.3	-3.3	0.3	1.1	0.0	0.0
	Velocity	-4.7	-1.3	0.1	0.3	0.0	0.0
4	RayDeformable	-0.6	-0.2	-0.2	0.2	0.8	-0.5
	SmartAdapt	-1.4	-1.4	-1.0	-0.8	-1.4	0.0
	Velocity	-1.4	0.0	-0.8	0.0	0.0	1.4
5	RayDeformable	-0.6	0.8	0.8	1.3	0.4	-0.3
	SmartAdapt	-1.3	0.7	0.0	0.0	-0.7	-0.7
	Velocity	-0.7	0.7	0.8	1.2	0.7	0.0
6	RayDeformable	-0.3	-0.3	-0.8	-1.0	-1.2	-1.2
	SmartAdapt	-3.0	0.0	-1.9	-1.9	-1.0	-3.0
	Velocity	-28.0	-4.0	3.4	-3.1	-1.0	0.0

***Table 1**. The difference in percentage units between dose calculations on the deformed patient images series and the target image series. Negative values indicate that the calculated dose or volume was lower in the deformed series than in the target series. All plans are normalized to 100% = prescribed dose. Values on blue background indicate a visually un-successful deformation of the structure.*

SAHLGRENSKA ACADEMY
DEPARTMENT OF RADIATION PHYSICS

UNIVERSITY OF GOTHENBURG