Evaluation of cranial setup accuracy: a double shell positioning system versus an in-house 3-point mask solution

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Motivation

Stereotactic radiotherapy (RT) requires very accurate and reproducible positioning, thus reducing the geometrical setup uncertainties and irradiated volume of normal tissue (brain).
In our clinic an in-house 3-point mask solution is currently used to fixate the patients during treatment. This mask, is already quite sufficient, but we would like to improve the reproducibility of the patient position even more. A promising candidate is the MacroMedics Double Shell Positioning System (**DSPS**)®. This new fixation system for cranial radiotherapy consists of a mouldable mask in combination with an also individually moulded head rest.

Objective

In this study we compare the setup accuracy and stability of patient positioning using the DSPS versus an in-house 3-point mask solution that is currently used for stereotactic brain RT .

Methods

27 stereotactic brain RT patients were immobilized using an in-house 3-point mask solution (Figure 1). These patients received their treatment in 3 fractions.
25 palliative cranial RT patients were immobilized using the DSPS (Figure 2). These patients received 5 or 10 RT fractions. In both systems a dental fixation (bite) is integrated to improve the fixation of the upper jaw and prevent pitch. To achieve this, the patients were asked to bite on a wooden spatula through the mask while the masks were moulded.
For all 52 patients, 3 conebeam computed tomographies (CBCT) were acquired at maximum 5 fractions. The first CBCT is used for positioning, the second CBCT is acquired in the treatment position just prior to irradiation, and the third CBCT is acquired directly after irradiation with the patient still in treatment position.

Figure 1*: The *in-house 3-point mask solution consists of a 3-point thermoplastic mask with bite and a soft 'individualized' headrest.

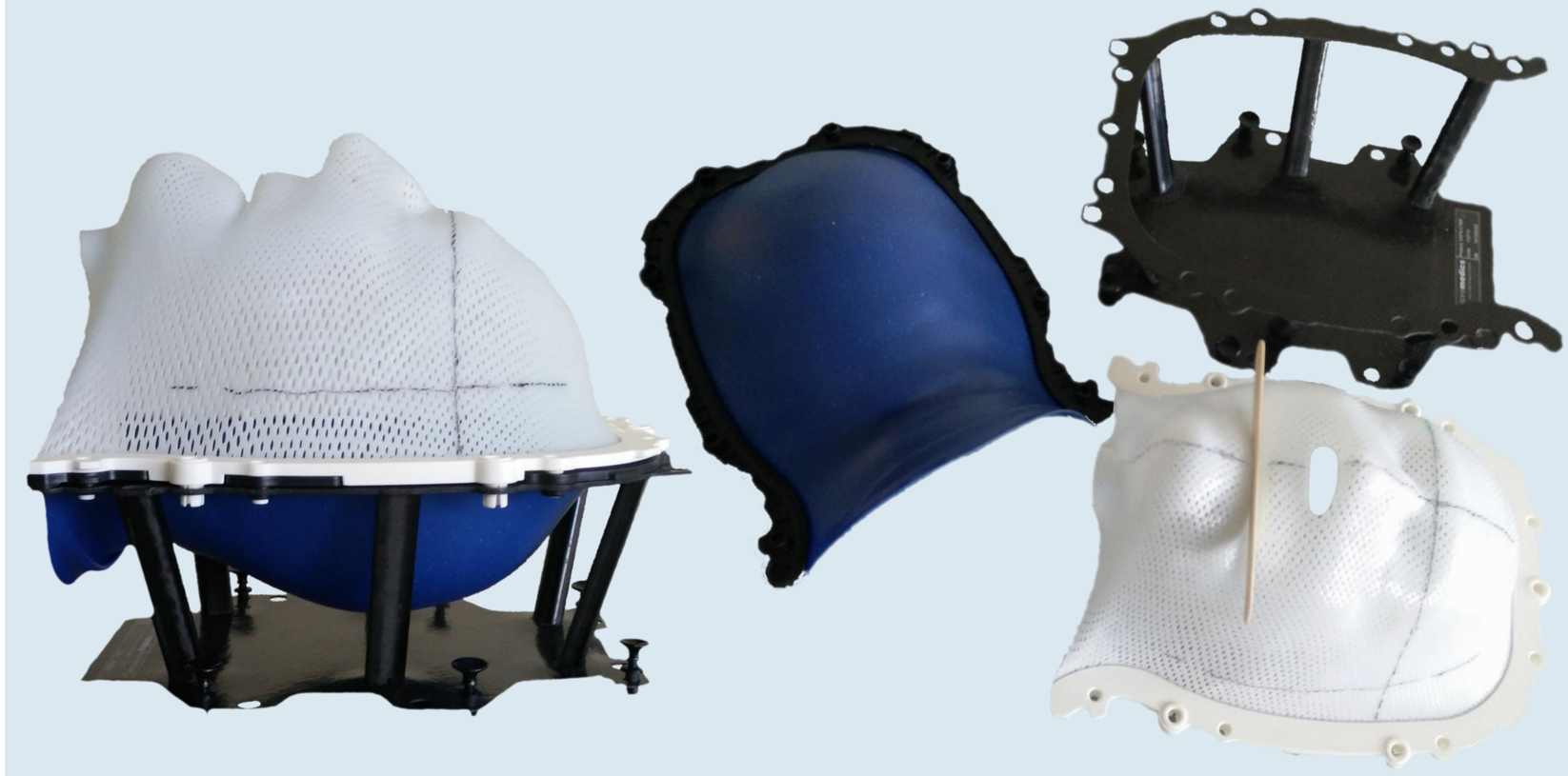

Figure 2: The MacroMedics DSPS consists of a carbon fibre cradle for fixation on the table and two different mouldable thermoplastic sheets .

Methods

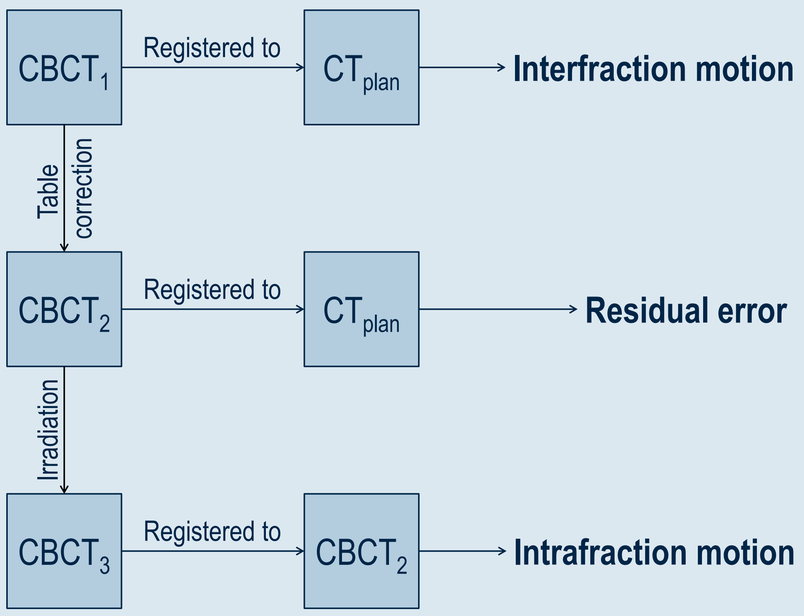

Figure 3: The errors of the interfraction motion represent alignment on lasers and lines on the mask The residual errors are the uncertainties after application of the setup correction. The intrafraction motion is the movement during the treatment.

The CBCT's are registered to the planning computed tomography's (CT_{plan}) or to each other (Figure 3). All registrations are performed with 6 degrees of freedom (DoF) and are based on the bony anatomy of the skull.
From these registrations, geometrical setup uncertainties (mean-of-means (**μ**), systematic (**Σ**) and random (**σ**) errors are calculated, as described by van Herk *(Sem. Rad. Oncol. 14(1) 2004: 52-64))*.

Results

The geometrical setup uncertainties for both fixation systems are shown in Table 1.
When these setup errors are used to calculate **setup** margins, using van Herk's formula:

$$M = 2{,}5\Sigma + 0{,}7\sigma$$ (Sem. Rad. Oncol. 14(1) 2004: 52-64)

the setup margins for the two fixation types are:

	Lateral	Longitudinal	Vertical
3-point mask	**1,7 mm**	**2,1 mm**	**2,0 mm**
DSPS mask	**1,0 mm**	**1,0 mm**	**1,1 mm**

Results

Table 1: Geometric uncertainties using different immobilization systems.

3-point mask

Interfraction motion (mm, °)	Lat	Lng	Vrt	Pitch	Rtn	Roll
μ	0,3	0,0	-0,2	0,1	0,1	-0,2
Σ	1,5	2,0	1,3	0,9	1,0	0,9
σ	1,9	1,8	1,1	0,5	0,6	0,6

DSPS mask

Interfraction motion (mm, °)	Lat	Lng	Vrt	Pitch	Rtn	Roll
μ	0,1	-0,2	0,4	0,3	0,0	-0,3
Σ	1,1	2,0	2,1	0,5	0,6	0,3
σ	1,1	2,1	4,3	0,5	0,5	0,3

3-point mask

Residual Error (mm, °)	Lat	Lng	Vrt	Pitch	Rtn	Roll
μ	0,0	0,1	-0,2	0,1	0,1	-0,2
Σ	0,4	0,6	0,7	0,8	0,4	0,8
σ	0,7	0,8	0,5	0,6	0,5	0,7

DSPS mask

Residual Error (mm, °)	Lat	Lng	Vrt	Pitch	Rtn	Roll
μ	0,0	0,1	0,2	0,3	0,1	-0,3
Σ	0,1	0,2	0,3	0,5	0,2	0,4
σ	0,3	0,4	0,6	0,6	0,3	0,3

3-point mask

Intrafraction motion (mm, °)	Lat	Lng	Vrt	Pitch	Rtn	Roll
μ	0,0	0,0	0,0	0,0	0,1	0,0
Σ	0,2	0,2	0,1	0,2	0,3	0,1
σ	0,3	0,3	0,1	0,1	0,3	0,2

DSPS mask

Intrafraction motion (mm, °)	Lat	Lng	Vrt	Pitch	Rtn	Roll
μ	0,0	0,1	0,0	0,0	0,0	0,0
Σ	0,2	0,1	0,0	0,1	0,1	0,0
σ	0,5	0,2	0,1	0,1	0,2	0,1

Discussion

In summary, the fixation with the 3-point mask solution is already quite satisfactory with **setup** margins of 2 mm. Yet, the DSPS seems to be able to give even better fixation. The **setup** margins can be reduced to 1 mm.
Nevertheless, planning target volume margins account for more uncertainties, and are therefore larger than this 1 mm. Besides that, one should be aware of some of the assumptions in this current analysis. The calculated uncertainties and setup margins are based on registrations with 6 DoF, while not all treatment tables are able to correct for pitch and/or roll. Rotations are also ignored in the margin calculation. In particular in patients with elongated target volumes this can give inaccurate results. Additionally, in this study, the clinical target volume itself is assumed to be in a completely stable position relative to the skull. Another limitation in this study is that the two patient groups have different populations. The treatment of the stereotactic patients consist of 3 fractions. For the palliative patients, we gathered ad 5 fractions data. Furthermore, the time between $CBCT_2$ and $CBCT_3$ is longer for the first group.

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