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The simple assessment of the effects of uncorrected rotational movements

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Background

- The treatment process flow
- The verification of the patient position
- The rotational errors

The method of assessment

- The rotation matrix
- The hypothetical point
- Results
- Conclusions

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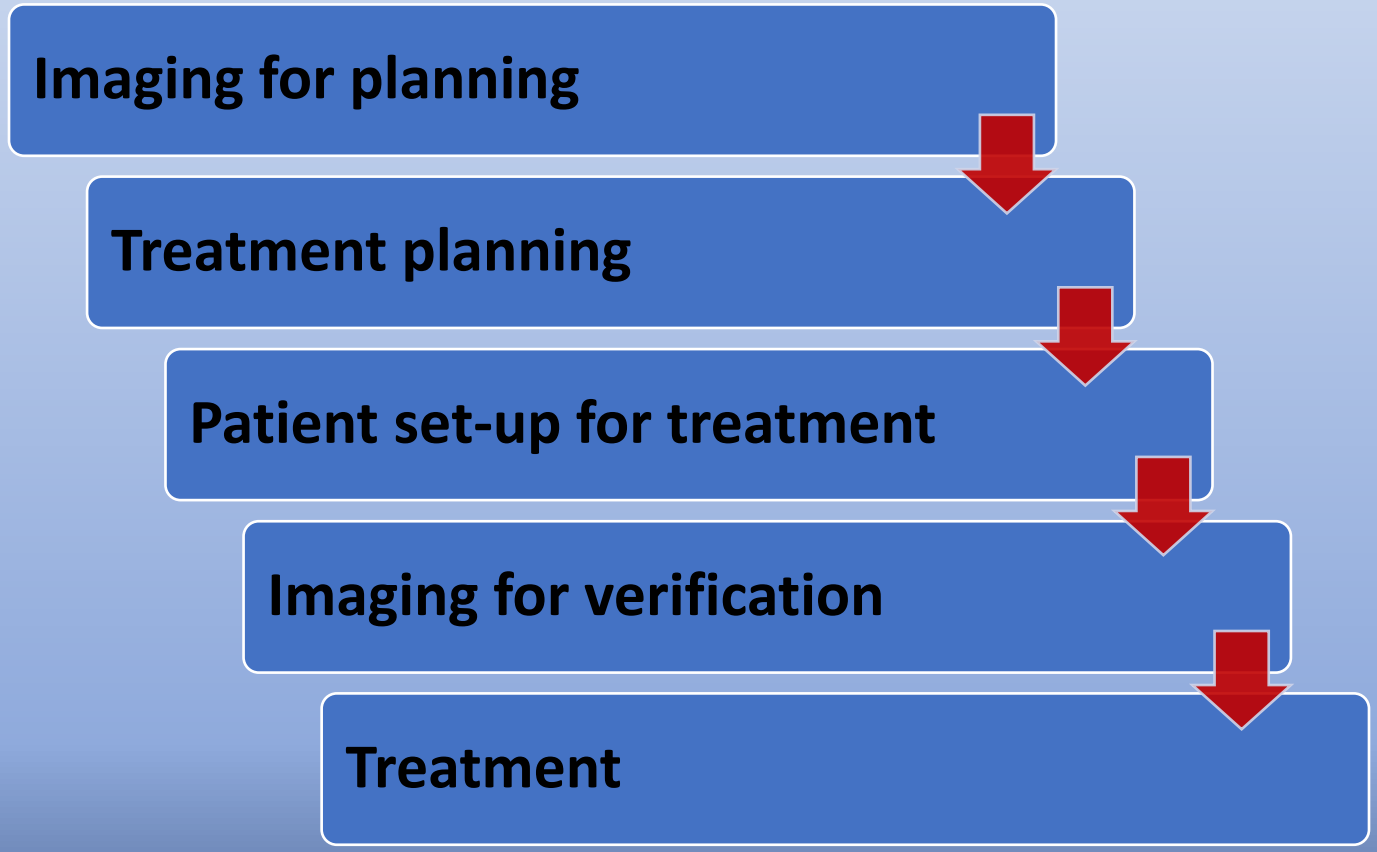
• The treatment process flow



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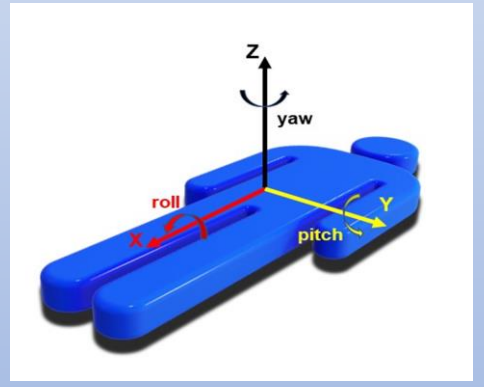
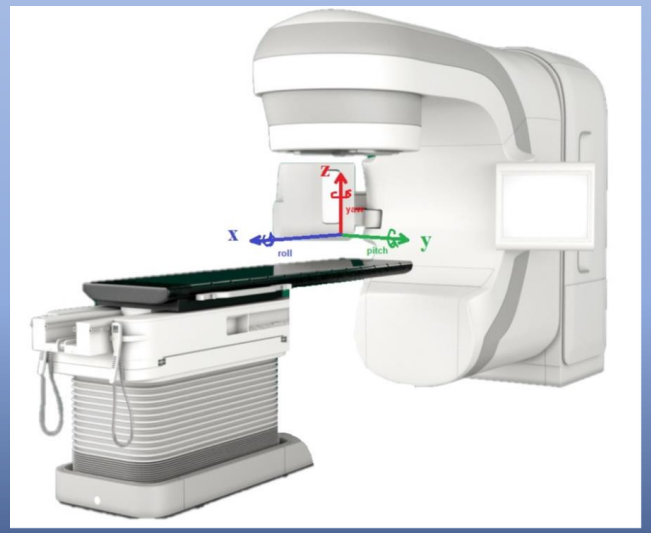
• The verification of the patient position

The information received after image verification:

- **Translations in X, Y and Z directions**
- **Rotations : roll, pitch and yaw**





Most linear accelerators are equipped with conventional couches that can be moved in X, Y, Z directions and perform <u>only</u> yaw rotation.

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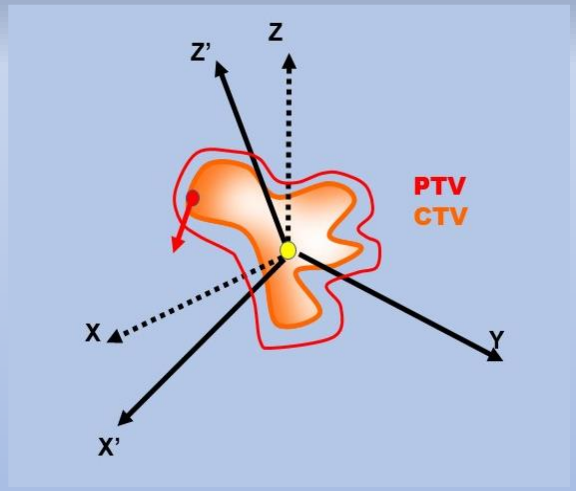
• The rotational errors

The translation caused by uncorrected rotations may be larger then CTV-PTV margin for irregular shape of CTV.

The part of CTV does not receive prescribed dose.



22 patients had daily CBCT scans (570 CBCTs in total) prior to the treatment delivery.

The angle of uncorrected rotation ranged from -3.8 to 1.6 degrees in roll and from -4.2 to 3.9 degrees in pitch direction.

77 of the 570 rotational errors were larger than 2,0 degrees in pitch direction and 11 of the 570 in roll direction.

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• The rotation matrix

The position of the point after rotation is calculated using a rotation matrix. The rotation matrix is formed by multiplying the yaw, pitch, and roll rotation matrices and is given by formula:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{pmatrix} \cos\alpha\cos\beta & \cos\alpha\sin\beta\sin\gamma - \sin\alpha\cos\gamma & \cos\alpha\sin\beta\cos\gamma + \sin\alpha\sin\gamma \\ \sin\alpha\cos\beta & \sin\alpha\sin\beta\sin\gamma + \cos\alpha\cos\gamma & \sin\alpha\sin\beta\cos\gamma - \cos\alpha\sin\gamma \\ -\sin\beta & \cos\beta\sin\gamma & \cos\beta\cos\gamma \end{pmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

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• The rotation matrix

The matrix describes the rotations in the following order:

γ - a counterclockwise rotation of about X axis (**roll**)

β - a counterclockwise rotation of about Y axis (**pitch**)

α - a counterclockwise rotation about the Z axis (**yaw**)

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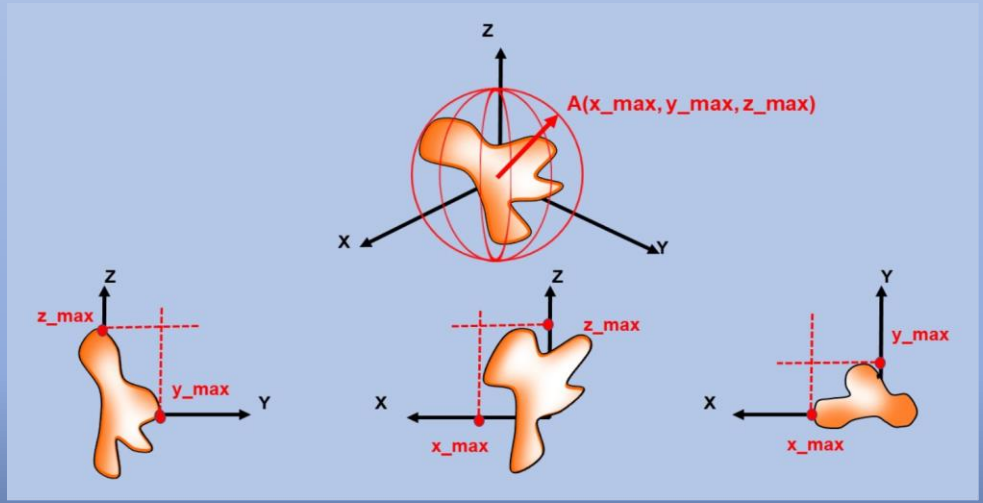
• The hypothetical point

Using the rotation matrix, we can calculate the position of all CTV points for each treatment session (time-consuming, the dedicated program for importing and analysing data from the system).

<u>For assessment, a hypothetical A point was created.</u>

The (x y z) coordinates of the hypothetical point A are equal to the maximum distance from the isocenter to the CTV border in the X, Y and Z axis directions, respectively. (It is easy to measure in the system.) The segment connecting the isocenter to the point A is the radius of the sphere that covered CTV.



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• Results

#	Distance in X direction [cm]	Distance in Y direction [cm]	Distance in Z direction [cm]
1	9,0	9,7	7,2
2	10,6	10,1	8,9
3	6,5	8,5	6,7
4	9,2	9,4	8,7
5	10,5	7,8	6,4
6	8,7	7,0	6,9
7	9,9	7,6	6,1
8	7,2	7,7	7,6
9	9,4	7,1	5,9
10	10,8	9,3	8,7
11	10,5	7,5	7,3
12	8,6	8,3	6,7
13	10,2	8,1	6,9
14	10,5	7,9	7,9
15	8,5	8,8	7,5
16	10,6	8,9	7,9
17	8,9	9,1	7,2
18	9,9	8,7	8,7
19	9,3	9,6	8,9
20	10,7	7,1	5,6
21	7,9	8,6	7,1
22	10,2	9,5	10,3

The maximal distance for the evaluated patients achieved value 10.8cm, 10.1cm and 10.3cm in X,Y and Z direction, respectively.

An uncorrected pitch rotation larger than 2 degrees caused shifts of about 3-4 mm in Z direction.

When additionally the uncorrected roll rotation is more then 0 degrees, the shifts are larger than 4 mm.

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• Results

For 22 patients :

2 patients had 5 from 28 fractions with shift ≥ 4mm X direction

5 patients had 5 from 28 fractions with shift ≥ 4mm Z direction

Additionally:

1 patient had 1 fraction with shift 8 mm in X direction

3 patients had 1 fraction with shift from 7mm to 1cm in Z direction

X direction:

The fractions with the shifts of point A larger than 4mm were noted for 9 patients.

Y direction:

The shifts larger than 4 mm were not noted.

Z direction:

The fractions with the shifts of point A larger than 4mm were noted for 12 patients.

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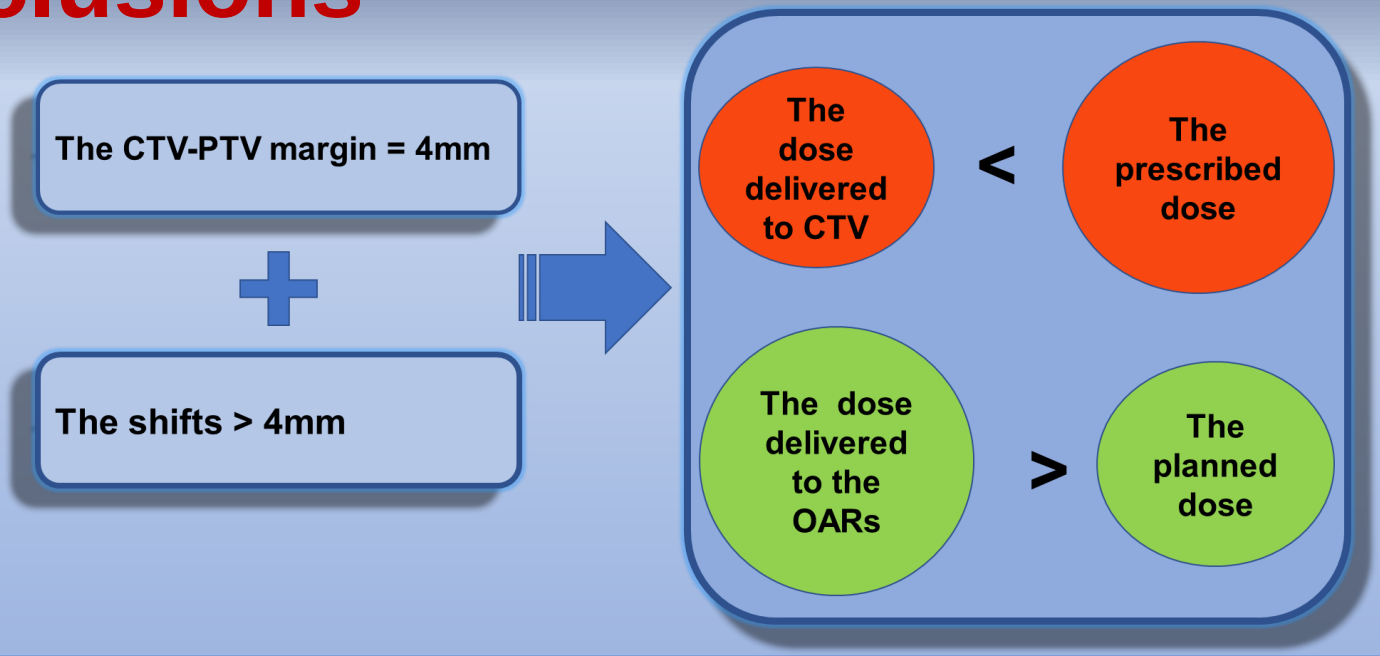
• Conclusions



The impact of rotational set-up errors should be taken into consideration in calculations of the CTV-PTV margin.

The presented method allows to calculate or assess the shifts caused by rotations.

This could be the basis for calculating CTV-PTV margin for a selected group of patients.

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Thank you for your attention!