Improving of the treatment procedure based on dose verification and deformable image registration

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Aim

The aim of the study was to estimate the dose deposited in the stomach and duodenum during radiotherapy and to compare it with the dose calculated in the treatment planning system.
Material and methods

- The patient with pancreatic cancer underwent radiotherapy. The prescribed dose was 45Gy in 25 fractions with a simultaneous integrated boost of 70Gy.
- The IMRT treatment plan (plan1) was prepared in the Eclipse™ Varian system based on computed tomography for planning (CT).
- Before each irradiation fraction, a control CT examination (CT-on rails images) was performed to assess the location of internal organs.
- During the treatment course, due to the changes in the patient's anatomy, two new plans were made: plan1a, plan1b based on new computed tomography for planning: CTa and CTb.
Material and methods

- Plan1 was implemented without Active Breathing Coordinator (ABC) (fractions from 1 to 4)
- Plan1a - ABC introduced (fractions from 5 to 15)
- Plan1b - the patient cooperated very well with the ABC system (fractions from 16 to 25)
Material and methods

• The calculations of the dose distribution were made based on control CT, maintaining the parameters of the treatment plan - the real dose distribution (rDD) was calculated taking into account the current patient anatomy for each radiation fraction.
• All rDD and control CT were imported into the VelocityTM Varian Medical software.
• The deformable registration of rDD and control CT were performed with planning CT as primary volume.
• The sum of the real dose distribution were created for plan 1 and CT, plan1a and CTa, plan1b and CTb .
• The calculated sums were imported into the Eclipse system and compared with the prepared plans.
The calculations of the dose distribution were made based on control CT in Eclipse system— the real dose distribution (rDD) for each fraction.

rDDs were imported into Velocity

The deformable registration and the sum of dose distribution were performed for plan1 and fractions 1-4, plan1b and fractions 5 - 15, plan1b and fractions 16 - 25.

The rDDs imported into Eclipse system were compared with planned dose distributions.
## Results

The doses delivered to duodenum and stomach – **plan1**

<table>
<thead>
<tr>
<th>duodenum</th>
<th>dose [cGy] - plan1</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>mean</td>
<td>median</td>
<td>moda</td>
</tr>
<tr>
<td>planned dose</td>
<td>34,5</td>
<td>804,9</td>
<td>472,9</td>
<td>501,6</td>
<td>709,1</td>
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<tr>
<td>real dose</td>
<td>31,3</td>
<td>910,3</td>
<td>418,8</td>
<td>460,9</td>
<td>498,2</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>stomach</th>
<th>dose [cGy] - plan1</th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>mean</td>
<td>median</td>
<td>moda</td>
</tr>
<tr>
<td>planned dose</td>
<td>15,2</td>
<td>595,3</td>
<td>152,6</td>
<td>69,4</td>
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<td>real dose</td>
<td>12,6</td>
<td>782,6</td>
<td>237,0</td>
<td>239,9</td>
<td>25,6</td>
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</table>
Results

The comparison of the dose volume distribution for duodenum and stomach – **plan1**
Results

Difference: (real dose minus planned dose) for **plan1**

Maximal volume difference: for duodenum **-10** percentage points, for stomach **+20** percentage points
Results

The dose distribution—plan1

planned

real
# Results

The doses delivered to duodenum and stomach – **plan1a**

<table>
<thead>
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<th>duodenum</th>
<th>dose [cGy] - plan1a</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>mean</td>
<td>median</td>
<td>moda</td>
</tr>
<tr>
<td>planned dose</td>
<td>57,7</td>
<td>2300,7</td>
<td>792,1</td>
<td>257,8</td>
<td>91,4</td>
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<tr>
<td>real dose</td>
<td>38,8</td>
<td>2477,7</td>
<td>562,9</td>
<td>113,9</td>
<td>65,8</td>
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<table>
<thead>
<tr>
<th>stomach</th>
<th>dose [cGy] - plan1a</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>mean</td>
<td>median</td>
<td>moda</td>
</tr>
<tr>
<td>planned dose</td>
<td>40,1</td>
<td>2007,7</td>
<td>559,3</td>
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</table>
Results

The comparison of the dose volume distribution for duodenum and stomach – plan1a
Results

Difference: (real dose minus planned dose) for **plan1a**

Maximal volume difference: for duodenum -26 percentage points, for stomach +17 percentage points
Results

The dose distribution—plan1a

planned

real

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The doses delivered to duodenum and stomach – **plan1b**

<table>
<thead>
<tr>
<th>duodenum</th>
<th>dose [cGy] - plan1b</th>
<th>stomach</th>
<th>dose [cGy] - plan1b</th>
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</thead>
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<td></td>
<td>min</td>
<td>max</td>
<td>mean</td>
</tr>
<tr>
<td>planned dose</td>
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<td>real dose</td>
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Results

The comparison of the dose volume distribution for duodenum and stomach – plan1b
Results

Difference: (real dose minus planned dose) for plan1b

Maximal volume difference: for duodenum -2 percentage points, for stomach +7 percentage points
Results

The dose distribution – *plan1b*

planned

real
Conclusion

• The organ localization verification based on CT-on rails images allows to significantly improve the control of irradiation conditions.

• The implementation of ABC results in remarkably high precision of delivering the prescribed dose and thus protection of the OARs.

• Deformable registration allows to determine the dose delivered to the OAR during treatment, which is essential in high-dose radiotherapy.