Choice of tomotherapy planning parameters for nasopharynx cancers

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Aim

Tomotherapy is a dedicated intensity modulated radiation therapy system with on-board imaging capability. It works with its own inverse planning system, which includes the use of a combination of pitch, jaw width, and modulation factor settings. Previous studies into the use of Tomotherapy for treating head and neck cancers, have shown that Tomotherapy can achieve a significant reduction of the integral dose [1] and in some instances improved dose conformity and homogeneity and improved sparing of organs at risk (OAR). The impact of Tomotherapy settings have already been studied but only with a limited number of patients, and from a range of tumour sites rather than focusing on similar cases.[2] We have expanded the work currently available in the literature by undertaking a study on a greater number of patients, while focusing specifically on one clinical site; nasopharynx. We have aimed to determine the best range of settings to use for nasopharynx cancer planning and also to look at the variation of the impact between patients.

To conduct this study, we have performed a dosimetric study over a range of nasopharynx cancer cases using different treatment planning system (TPS) settings: Different Pitches (0.430, 0.286), jaw width (5cm, 2.5cm, and 1 cm) and jaw modes (static, dynamic) were used and their impact on plan quality quantified.
Methods and materials

Ten patients previously treated with different stages of Nasopharynx cancer were selected.

Eight parameter variations were used to optimise tomotherapy plans for each patient, using different combinations of; jaw modes (static, dynamic), jaw widths (1cm, 2.5cm, 5cm), and pitch (0.287, 0.43).

Planning priorities have been defined in accordance with RTOG 0615 and local experience. First step has been to spare the following « critical » organs at risk: brainstem, spinal cord, optic chiasm, optic nerves, mandible with Dmax thresholds respectively of 54Gy, 45 Gy, 54Gy, 54Gy, 70Gy. Then we focused on dose to target objectives: V95 %< 95% and D1 %< 107% for PTV coverage and V100%> 98% for CTV coverage. Then we optimized salivary glands (parotids, oral cavity), and finally the other OAR. If all these criteria were met, we tried to improve further: coverage, conformity and dose to parotids, without compromising the other objectives.

Resulting plan quality was quantified using conformity index (CI) and dose homogeneity index(DH) ,dose to organs at risk (OAR), integral dose(ID) and treatment time.[Fig. 1]
1. **Dose homogeneity in target volumes**
   \[
   DH = \frac{(D_{\text{max}} - D_{\text{min}})}{D_{\text{ref}}}
   \]

2. **Conformity index for PTV 70 Gy**
   \[
   CI = \frac{(\text{Prescribed isodose volume in tumour})^2}{(\text{Tumour volume}) \times (\text{Prescribed isodose volume})}
   \]

3. **Dose to organs at risk**
   \[
   D_{1\%}, D_{5\%}, D_{\text{mean}}
   \]

4. **Global dose to patient**
   A) Volume of the 10 Gy isodose
   B) Integral dose to the upper part of the body (from top of the skull to T6 vertebra):
   \[
   ID = D_{\text{mean}} \text{(Gy)} \times \text{volume (cm}^3\text{)}
   \]

**Fig. 1:** Plan quality assessment indexes

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Results

1. JAW WIDTH COMPARISON

As expected, jaw width (JW) had a major impact on plan quality compared to other parameters

Reducing JW lead to a general improvement in plan quality, especially in terms of target coverage (both conformity and homogeneity). In terms of dose to OAR, for early stage patients, all dose objectives could be achieved even with the largest JW (5 cm). However for complicated cases, reducing JW can improve target doses and ensure OAR tolerances are achieved.[Fig. 2][Fig. 3]

If significant improvement could be achieved in plan quality, treatment time also increased dramatically. The average treatment time per session was quantified as 3.2 min, 5.6 min and 13.7 min for respectively 5, 2.5 and 1 cm JW.

2. STATIC/DYNAMIC

The use of dynamic instead of static jaws showed a general reduction of dose to healthy tissues in every patient:

For 5 cm JW, the 10 Gy isodose volume could be reduced by 17.9 % (±2.5%) and the integral dose to the upper part of the body (volume defined from the top of the skull to T6 vertebra) by 11.4% (±1.9%). For 2.5cm JW, the impact was found to be less important however a decrease of 7 % (±4.5%) and 4.2 % (±1.2%) was still observed. [Fig. 4]

<table>
<thead>
<tr>
<th>Jaw width</th>
<th>2.5 cm</th>
<th>5 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing Integral dose</td>
<td>4.2 % (± 1.2%)</td>
<td>11.4 % (± 1.9 %)</td>
</tr>
<tr>
<td>Reducing 10 Gy isodose V.</td>
<td>7.0 % (± 4.5 %)</td>
<td>17.9 % (± 2.5 %)</td>
</tr>
<tr>
<td>Treatment time increase</td>
<td>8 sec (total:5 min)</td>
<td>5 sec (total:3 min)</td>
</tr>
</tbody>
</table>

On average dynamic jaws also slightly improved conformity, homogeneity and OAR sparing, for some patients with tumours located close to OAR in cranio caudal direction.

In addition, the use of dynamic instead of static jaws did not increase treatment time.
3. Pitch

Plans optimised with a pitch of 0.287 showed a slight improvement in conformity index (CI) and Dose Homogeneity (DH) compared to a pitch of 0.43, but no changes in doses to OAR were observed. [Fig. 5]
Fig. 2: Dose to OARs for 2.5 cm and 5 cm JW in comparison to 1 cm JW

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Fig. 3: Isodose Curves obtained with the use of 3 different Jaw widths for the same patient. In that case optic chiasma is located right on the top of the tumour: the influence of JW on Dmax to optic chiasma is really important.

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Fig. 4: Variations in the integral dose between static & dynamic JW for 2.5 and 5 cm

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Fig. 5: Dose to OARs comparison between pitch of 0.287 and 0.43

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Conclusion

Jaw width (JW) had a major impact on plan quality and treatment time. As expected, a smaller JW resulted in better conformity and improved target coverage. We also observed a general reduction of doses to OAR with high inter-patient variability. Patients with critical structures right next to target volumes in craniocaudal (CC) direction benefited most from the lower JW. This can be explained by the variation of the Jaw width only in that direction due to the design of the Tomotherapy unit. Different patient anatomy and tumour localisation explain the very high inter-patient variability for OAR such as chiasma or oral cavity. Reducing JW might be particularly interesting in patients with tumours close to OAR in the CC direction. The gain in terms of homogeneity and conformity could also justify the use of 2.5cm instead of 5cm JW.

In terms of treatment time, both 2.5 and 5 cm JW seems acceptable. With an average treatment time of 13.8 minutes, the use of 1 cm JW is not clinically realistic, and patient movement uncertainties during a longer treatment could reduce to zero the benefit of the use of the 1 cm JW.

Changes in pitch values showed no significant differences in plan quality but increased treatment time by an average of 16 % (±10%). The use of a pitch of 0.430 should be the standard when treating nasopharynx cancers. In extreme cases, one could try with 0.287 to achieve a very slight improvement but with poor "benefits to treatment time" ratio.

Dynamic jaws reduced unnecessary irradiation to healthy tissues for all patients while slightly improving conformity, homogeneity and dose to OAR without increasing treatment time. If available, this option should be used all the time. However, in terms of plan quality, 5 cm dynamic is closer to 5 cm static than to 2.5 cm JW performances. 2.5 cm static were still superior to 5cm even with the use of dynamic jaws. However an aspect to take into account in this decision is the reduced treatment time when using 5 cm dynamic instead of 2.5 cm JW.

As a conclusion we would suggest using the following settings when optimizing NPC plans:

2.5 cm JW with a pitch of 0.430 and with dynamic mode enabled if available.

The contribution of dynamic jaws for 5 cm JW could lead to the use of that setting for early stages NPC.
On the contrary, if the tumor stage is very advanced and the planner struggling with constraints, the potential of increasing the pitch to 0.287 or a reduction in JW to 1 cm could be considered noting that this is likely to provide relatively small improvements and a large increase to treatment time.
**Fig. 6**: The relative impact of the planning parameters. The number of '+' represents an increase in the metric on the left, 'NO' refers to no impact.

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References


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