Chapter 4

The dose to the parotid glands with IMRT for oropharyngeal tumors: the effect of reduction of positioning margins

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Abstract
Purpose: The aim of this paper is to quantify the importance of the reduction of positioning margins applied to the clinical target volume (CTV) on the dose distribution of the parotid gland for different intensity modulated radiotherapy (IMRT) strategies for the treatment of oropharyngeal cancer.
Methods and Materials: CTVs and organs at risk were delineated in the planning computed tomographic (CT) scans of three patients. Margins of 0, 3, 6 and 9 mm were applied to the CTVs in order to obtain the planning target volumes (PTVs). Three IMRT strategies were used to optimize the dose distribution.
Results: The analysis of the three IMRT strategies resulted in: (1) an optimal dose distribution in the PTV, (2) optimal dose distribution in the PTV while sparing the parotid gland and (3) more parotid gland sparing but at expense of the dose homogeneity in the PTV. The mean parotid dose increased linearly with increasing margin by approximately 1.3 Gy per mm. As a result the normal complication probability (NTCP) for xerostomia decreased when smaller margins were applied. Reducing the margin from 6 to 3 mm resulted in an NTCP reduction of approximately 20 %.
Conclusion: Reducing the CTV-PTV margin by improving the patient position accuracy may lead to a significant reduction of NTCP for the IMRT treatment of the oropharyngeal tumors and lymph nodes level II.
4.1 Introduction

A common and severe complication of the irradiation of cancers in the head and neck region is xerostomia. The level of xerostomia for an individual case depends on the location of the main salivary glands relative to the target volumes. In case of oropharyngeal tumors, at least one parotid gland is located near the primary tumor and both are located adjacent to the lymph node containing region level II, which are treated electively. Irradiation of the main salivary glands is therefore inevitable, which can cause reduction of the salivary flow and change in salivary composition leading to a number of clinical sequela including xerostomia, difficulties in mastication and speech, changes of taste, increased risk of caries and oral infections, chronic esophagitis and altered nutrition (Hamlet et al., 1997; Mandel, 1987; Vissink et al., 1988; Wright, 1987). These severe side effects have a negative impact on the quality of life of the patient (De Graeff et al., 1999; Huguenin et al., 1999).

Conventionally two opposed lateral fields are used for the irradiation of the oropharynx. Therefore dose values up to the prescribed dose (50-70 Gy) cannot be avoided to the parotid glands. In a prospective study Roesink et al. (2001) showed that a normal tissue complication probability (NTCP) of 50 % for xerostomia is obtained when the mean dose to the parotid glands is 39 Gy. Eisbruch et al. (1999) reported a mean dose of 28.4 Gy for a NTCP of 50 %. Lower NTCP values (< 50 %) and thus lower mean doses are, however, desirable.

Various studies showed reduction of the dose to the parotid glands using intensity modulated radiotherapy (IMRT) (De Neve et al., 1999; Butler et al., 1999; Wu et al., 2000; Manning et al., 2001; Eisbruch et al., 1998). With IMRT it might therefore be possible to preserve the function of the parotid glands, while the target volumes still receive an acceptable dose. The reduction of the dose is depends on the exact implementation of the IMRT technique, which determines the steepness of the dose gradient between the parotid glands and the PTVs. Secondly, the margins applied to the clinical target volume (CTV) in order to obtain the planning target volume (PTV) are important. These margins can cause overlapping areas between the PTVs and the parotid glands, unavoidably leading to high dose regions in these glands. The size of these margins depends on set-up uncertainties (Hurkmans et al., 2001b; De Boer et al., 2001) and organ motion. Improving the positioning of patients and position verification results in smaller margins, and might consequently result in a lower NTCP for xerostomia.

It is the purpose of this work to quantify the influence of the CTV-PTV margin, i.e. the importance of more accurate position verification, on the dose distribution of the parotid glands and secondly to investigate the influence of different IMRT strategies to the dose to the parotid glands and the PTVs for the irradiation of oropharyngeal tumors and lymph nodes level II.
4.2 Materials and method

4.2.1 Patients

The data of three patients with oropharyngeal tumors were used. Patient A had a tumor localized in the anterior faucial pillar (T1N0M0), patient B had a tumor localized in the tonsil (T2N0M0) and the tumor of patient C was localized in the vallecula (T3N0M0). A planning computer tomography (CT) with 3 mm slice intervals was available for these patients. The CT-images were transferred to our treatment planning system (PLATO RTS 2.4, Nucletron Ltd., Veenendaal, NL), where the CTV of the lymph node containing regions, the CTV of the primary target and the organs at risk (OAR; the parotid glands, the brain and the spinal cord) were delineated by a physician. According to the protocol used in our department, the margins applied to the GTV to obtain the CTV of the primary tumor differ for each direction: 2 cm cranial; 1 cm caudal, ventral and medial; 0.5 cm lateral and dorsal. For the delineation of the CTV of the lymph node containing regions the guidelines of Wijers et al. (1999) and Nowak et al. (1999) were used. The volumes of the CTVs of the primary tumor were 97.2, 70.2 and 68.6 cm$^3$ for patient A, B and C, respectively. The mean volume of the parotid glands was 26.3 cm$^3$ (range 22.4–31 cm$^3$).

Margin of 0, 3, 6 and 9 mm were applied to the CTV in three dimensions using an automatic volume extension (PLATO VSS). This resulted in four different PTVs for each of the three CTVs of an individual patient (Fig. 4.1). The margin was a multiple of 3 mm since the CT was taken with 3 mm intervals. The extension of the CTV was limited in the region containing the skin, where the PTV was adjusted by hand when necessary to assure a minimal distance of 5 mm between the PTV and then skin. The minimal margin between a PTV and the spinal cord was approximately 10 mm. An extra volume was delineated around the PTV of the primary target with a margin of 5 mm to the PTV in order to steer the dose distribution. The optimization program can be forced to deliver the build-up of the dose to the prescribed dose to the primary PTV inside this extra volume. Thus when the primary PTV overlaps with the PTV of the lymph node containing region, the dose gradient from the dose prescribed to the lymph node containing region (54 Gy) to the dose prescribed to the primary target (66 Gy) will be located in this volume.

4.2.2 Intensity modulated radiotherapy planning

IMRT plans are generated using the inverse treatment planning module ITP of PLATO. This module is a commercially available version of the KonRad program, developed by the Bortfeld group (Bortfeld and Schlegel, 1993). The ITP module optimizes the fluence for a fixed beam geometry to obtain a dose distribution that best fits a series of dose constraints. For the target volumes a maximum and
minimum dose is specified, for OARs only a maximum dose. The relative weight of these constraints is tuned with so-called 'penalties'. All dose constraints are related to a given contour. Therefore the judicious choice of contours is important for dose painting.

During the optimization, a fluence matrix for each beam angle is generated and iteratively adjusted resulting in a dose distribution matching the prescription as closely as possible. For delivering such a fluence in practice, we plan to use step-and-shoot IMRT, i.e. the modulated fluence is realized by delivering a discrete number of irregularly shaped fields. The theoretical fluence with a continuous intensity distribution is converted into a deliverable fluence with distinct intensity
levels using sequencer software developed at our institute and incorporated into the ITP software. The fluence matrix had a resolution of $1 \times 1$ cm$^2$ in the isocenter. The resolution of the dose calculation matrix, for the iterative dose optimization, is 2.9 mm. After optimization, the dose distribution is recalculated with a three-dimensional (3D) planning system (PLATO RTS version 2.4) using a resolution of 1.6 mm for the dose calculation matrix.

The prescribed dose to the PTV of the primary tumor was 66 Gy (2.2 Gy/fraction; five times weekly), which is radiobiologically similar to 70 Gy (2 Gy/fraction; five times weekly). For the elective irradiation of the lymph node containing regions 54 Gy (1.8 Gy/fraction; five times weekly) was prescribed, equivalent to 50 Gy in 25 fractions. The dose to the target volumes was delivered in a total of 30 fractions, resulting in a simultaneous integrated boost strategy, i.e. different dose levels are simultaneously delivered to different tissues in a single treatment session (Mohan et al., 2000). The maximum dose to the brain and the spinal cord was 45 Gy.

In order to achieve a standard set of beam parameters and dose constraints which can be used for the IMRT calculations, the number of beams and the value of the penalties were systematically varied. This resulted in a beam geometry consisting of seven coplanar beams equidistant, with the gantry angle of the first beam at $0^\circ$. Beside the beam geometry, a standard set of dose constrains (Table 4.1) was determined, which resulted in homogeneous dose distributions within the target volumes and acceptable doses to the organs at risk. Fifteen intensity levels were chosen for each beam. This is the maximum which can be chosen for step-and-shoot IMRT.

For each margin, three different optimization strategies concerning the sparing of the parotid glands were analyzed. In other words, three different sets of dose constraints for the parotid glands are used in this paper:

**set 1** The dose to the parotid gland is not taken into account during the optimization process of the target volumes.

**set 2** A penalty is assigned to the parotid gland which limits the dose during the optimization process. The parotid is thus actively spared.

**set 3** A more extreme version of the second set (a higher penalty), where the optimization process is forced to reduce the dose to the parotid glands further.

The penalty settings for the parotid glands were 0, 1 and 10 for dose constraint set 1, 2 and 3 respectively. The three different sets were used to determine the amount of parotid sparing that can be achieved and to investigate the relation between the sparing of the glands and the dose distributions in the PTVs.

It should be realized that the beam geometry and the set of dose constraints for the volumes involved where the same for all 36 (3 patients $\times$ 4 margins $\times$ 3dose constrain sets for the parotid glands) IMRT plans, the constraints of the parotid glands excluded.
Table 4.1: The settings used for the optimization in PLATO ITP. The penalty setting for the parotid glands (x) is varied.

<table>
<thead>
<tr>
<th>VOI</th>
<th>max dose</th>
<th>penalty</th>
<th>min dose</th>
<th>penalty</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV(_{primary\ tumor})</td>
<td>66</td>
<td>100</td>
<td>66</td>
<td>100</td>
</tr>
<tr>
<td>PTV(_{build-up})</td>
<td>66</td>
<td>100</td>
<td>66</td>
<td>1</td>
</tr>
<tr>
<td>PTV(_{lymph\ node})</td>
<td>54</td>
<td>100</td>
<td>54</td>
<td>100</td>
</tr>
<tr>
<td>Body</td>
<td>40</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spinal cord</td>
<td>30</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brain</td>
<td>30</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Parotid gland</td>
<td>20</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

4.2.3 Analysis

In our institute the salivary function of 108 patients treated with radiotherapy for various malignancies in the head and neck region was studied in detail (Roesink et al., 2001). The data were fitted using the NTCP model proposed by Lyman (1985). The data analysis showed that the mean dose to the parotid glands is a predictor for the salivary function of the glands after radiotherapy and can be used to calculate the NTCP. Therefore we calculated the mean dose to the parotid glands in order to predict the NTCP value for the IMRT plans. Beside the data of Roesink et al. (2001), the data of Eisbruch et al. (1999) were used to compare the results for two different clinically obtained NTCP curves. Both used a maximum likelihood estimation of the NTCP model but found different parameter values. For the same endpoint, i.e. less than 25 % of the baseline flow value at 1 year post-radiotherapy, Roesink et al. (2001) found TD\(_{50}\) = 39 Gy and a slope m = 0.45 versus a TD\(_{50}\) = 28.4 Gy and slope m = 0.18 reported by Eisbruch et al. (1999). A smaller value for m results in a steeper NTCP curve.

A two-tailed paired t-test, using the Bonferroni correction for multiple testing, was used for statistical analysis of the mean dose. In the remainder of this paper, differences were considered to be statistically significant when P < 0.05. Beside the analysis of the dose volume histograms (DVHs), the dose to the PTVs was evaluated by calculating the dose received by 95 % of the PTV (D\(_{95}\)), the dose received by 5 % of the PTV (D\(_{5}\)) and the mean dose. For the spinal cord and the brain, the dose received by 1 cm\(^3\) (D\(_{max}\)) was evaluated, which is used as an indicator of the maximum dose. The PTV of the primary target partially overlaps the lymph node containing region (Fig 4.1). In the analysis of dose distribution of the lymph node containing region, only the part of the lymph nodes which is not overlapping the PTV of the primary tumor is taken into account.
4.3 Results

4.3.1 Target volumes

In general, highly conformal dose distributions were obtained using seven beams and 15 intensity levels (Fig. 4.2). The mean dose to the various PTVs was close to the prescribed dose. The average mean dose (averaged over all 36 plans) to the PTV of the primary tumor was 66.2 Gy (range 65.4–67 Gy). For the PTV of ipsilateral and contralateral lymph node containing region this the average mean dose was 54.8 Gy (range 54.4–55.3 Gy) and 54.5 Gy (range 53.7–55.2 Gy) respectively. The homogeneity of the dose distribution was different for the three sets of dose constraints. The dose distribution calculated using set 1 or 2 were comparable when the same margin was applied (Fig. 4.3), indicating that parotid sparing was obtained without compromising the dose homogeneity in the PTVs. However, using the dose constrain set 3, part of the lymph node containing regions did receive a lower dose compared to the calculations for set 1 and 2 (Fig. 4.3). This was the case

Figure 4.2: Dose distribution in a transversal plane obtained using 7 equidistant beams. A margin of 6 mm and dose constrain set 2 were used. The isodose of 30, 40, 51.3 (= 95 % of 54 Gy) and 62.7 (= 95 % of 66 Gy) Gy are shown. Furthermore the contours of the volumes of interest are shown.
for all patients and all margins used. The dose distributions of the PTVs calculated for larger margins were slightly more inhomogeneous. The difference between $D_{95}$ and $D_5$, which characterizes the slope of the DVH, did not exceed 1 Gy for the PTV of the primary tumor and the contralateral lymph containing region when enlarging the margin for the same dose constrain set. In other words, 90 % of the volume received a dose within a dose interval of 1 Gy. For the ipsilateral lymph node containing region, values up to 2 Gy were calculated for a margin of 9 mm.
4.3 Results

Figure 4.4: The mean dose to the ipsilateral parotid gland of patient B as a function of the margin applied to the CTV for 3 dose constrain sets.

4.3.2 Spinal cord and brain

The maximum dose to the spinal cord and the brain were well below 45 Gy (table 4.2). The dose to the brain was not exceeding 42.9 Gy and the dose to the spinal cord was not exceeding 32.5 Gy for all plans. The average $D_{max}$ of the spinal cord was similar for the three patients with relatively small ranges. The variation in the $D_{max}$ of the brain was however larger and differed from patient to patient. In contrast with the $D_{max}$ of the spinal cord, the $D_{max}$ of the brain increased slightly when the margin was enlarged.

4.3.3 Parotid gland

The mean dose to the parotid gland was largely influenced by the IMRT strategy (Table 4.3). Using set 2, the mean parotid dose was reduced compared to the calculation using set 1 by approximately 6 Gy. For dose constrain set 3 the mean

<table>
<thead>
<tr>
<th>Patient</th>
<th>Brain average $D_{max}$ (range) [Gy]</th>
<th>Spinal cord average $D_{max}$ (range) [Gy]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>30.5 (25.6–34.7)</td>
<td>31.5 (30.4–32.3)</td>
</tr>
<tr>
<td>B</td>
<td>37.5 (32.6–42.9)</td>
<td>29.9 (28.9–30.7)</td>
</tr>
<tr>
<td>C</td>
<td>23.8 (18.6–29.6)</td>
<td>30.1 (29.1–31.5)</td>
</tr>
</tbody>
</table>
Table 4.3: The average mean dose (SD ≤ 8 %) to the parotid glands (D) and the NTCP (using the data of Roesink et al. (2001)) of the parotid glands for three sets of dose constraints and four different margins between the CTV and PTV.

<table>
<thead>
<tr>
<th>margin [mm]</th>
<th>0</th>
<th>3</th>
<th>6</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>D [Gy]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTCP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>34.9</td>
<td>0.41</td>
<td>38.4</td>
<td>0.49</td>
</tr>
<tr>
<td>set 1</td>
<td>28.6</td>
<td>0.28</td>
<td>32.3</td>
<td>0.35</td>
</tr>
<tr>
<td>set 3</td>
<td>21.5</td>
<td>0.16</td>
<td>24.3</td>
<td>0.20</td>
</tr>
</tbody>
</table>

The mean parotid dose increased approximately linearly with increasing margin, for all parotid glands and the various set of dose constrains used (Fig. 4.4). The relation between the margin and the mean dose was fitted by linear regression, for each gland and for every dose constrain set separately. This resulted in an average slope of $1.3 ± 0.2$ (1 SD = standard deviation) $\frac{\text{Gy}}{\text{mm}}$ for 18 fits. Consequently, when the margin is increased by 1 mm, the mean dose to the parotid gland will increase by approximately 1.3 Gy. The differences in mean dose between the IMRT plans calculated using the three different sets and between the four different margins were all statistically significant ($P < 0.001$).

NTCP values (Table 4.3) were calculated using the averaged mean dose of the parotid glands and the NTCP data of Roesink et al. (2001). The range of NTCP values was 0.16 – 0.63, depending on the margin and the IMRT strategy. The relation between the margin and the NTCP was also approximately linear (Fig. 4.5 A). When a margin of 6 mm was used together with dose constraint set 2, i.e. sparing of the parotid glands without compromising the dose homogeneity in the PTVs, the average NTCP was 0.44. Using a margin of 3 mm the NTCP reduced by approximately 20 % to a value of 0.35. The NTCP values were also calculated using the data of Eisbruch et al. (1999) (Fig. 4.5 B). Only for set 3 (NTCP range 0.09–0.80) and set 2 (NTCP range 0.54–0.98), with small margins, low NTCP values could be achieved using the data of Eisbruch et al. (1999). The range calculated for set 1 was 0.90–1.00.

For each margin, the PTVs are overlapping the parotid glands. The result is that a smaller part of the parotid gland (table 4.4) could be spared during the optimization process when the margin was increased. The volume of the parotid gland overlapped by the PTVs, relative to its original volume (relative overlapping volume) correlated linearly with the mean dose (Fig. 4.6). The data were fitted by linear regression. When the relative overlapping volume of the parotid glands in-
### 4.4 Discussion

In this work, the influence of the margins applied to the CTV on the dose to the parotid gland for the treatment of oropharyngeal cancer was quantified. As expected the mean dose to the parotid glands increased when the margin between the CTV and the PTV was enlarged. The parotid gland will, however, receive a substantial dose even for very small margins, since it is located adjacent to the lymph node containing region level II. The correlation between the mean dose and the margin was approximately linear, with a slope of $1.3 \text{ Gy mm}^{-1}$, i.e. enlarging the margin by 10%, the mean dose to the parotid glands increased by approximately 3.5 Gy.

### Table 4.4: The volume [cm$^3$] of the parotid glands (I = ipsilateral, C = contralateral) that is not overlapping the PTVs for 0, 3, 6, 9 mm margin between the CTV and the PTV.

<table>
<thead>
<tr>
<th></th>
<th>patient A</th>
<th>patient B</th>
<th>patient C</th>
</tr>
</thead>
<tbody>
<tr>
<td>margin</td>
<td>I</td>
<td>C</td>
<td>I</td>
</tr>
<tr>
<td>0</td>
<td>27.4</td>
<td>31</td>
<td>26.1</td>
</tr>
<tr>
<td>3</td>
<td>25.5</td>
<td>29.8</td>
<td>24.8</td>
</tr>
<tr>
<td>6</td>
<td>23.1</td>
<td>27.5</td>
<td>22.5</td>
</tr>
<tr>
<td>9</td>
<td>20.4</td>
<td>24.9</td>
<td>19.9</td>
</tr>
</tbody>
</table>

### Figure 4.5: The correlation between the NTCP and the margin applied to the CTV calculated for 3 dose constrain sets using the data of Roesink et al. (2001) (a) and Eisbruch et al. (1999) (b). Data of Fig. 4.4 are used.
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Figure 4.6: The correlation between the mean parotid gland dose and the relative overlapping volume of the parotid gland, i.e. the volume that is overlapping the PTV, for 3 dose constrain sets. The data are fitted by linear regression \( y = ax + b \): \( y_{\text{set 1}} = 0.33x + 35.7 (r = 0.66, \text{dashed line}), y_{\text{set 2}} = 0.33x + 29.7 (r = 0.72, \text{solid line}) \) and \( y_{\text{set 3}} = 0.35x + 20.0 (r = 0.84, \text{dotted line}) \)

the CTV-PTV margin with 1 mm results in an increment of the mean dose to the parotid gland of approximately 1.3 Gy. Consequently, the NTCP decreased for smaller margins. Decreasing for example the margin from 6 to 3 mm, without compromising the homogeneity of the dose distribution in the lymph nodes, results in a reduction of 20% in NTCP, showing the benefit of reducing the margins.

The dose distribution has been analyzed for three different dose constrain sets, resulting in: an optimal dose distribution in the PTV (set 1), optimal dose distribution in the PTV while sparing the parotid gland (set 2) and more parotid gland sparing but at the expense of the dose homogeneity (set 3). Using set 2 instead of 1, it is possible to reduce the dose to the parotid gland while the dose distribution to the PTVs remains the same. Using set 3 it is possible to reduce the dose to the parotid glands further, but part of the lymph node containing regions received a lower dose compared to the calculations for set 1 and 2 (Fig. 4.3). This was the case for all margins used. Although the NTCP could be decreased substantially, for example for a fixed margin of 6 mm and using set 3 instead of set 2 the NTCP was reduced from 0.44 to 0.28, these low dose regions might cause a lower TCP for the lymph node containing regions. Using set 3 instead of set 2 might thus have clinical consequences, not only for the NTCP but also for the TCP. When reducing the dose to an OAR, the dose distribution within the target volumes should be carefully monitored. It should therefore be investigated whether these
4.4. Discussion

Low dose regions in the elective PTV are of high risk regarding local failure, before dose reduction to the parotid glands using set 3 can be applied. The mean volume of the parotid glands was 26.3 cm$^3$ (range 22.4–31.0 cm$^3$), which is comparable to the mean value of 26.4 cm$^3$ (range 12.9–46.4 cm$^3$) reported in literature (Roesink et al., 2000). Consequently, in this work no extreme volumes of the parotid gland were studied. More extreme volumes of the parotid glands or parotid glands which are located more caudal or cranial, probably show a similar dependency of the mean dose on the margin. Since the mean dose depends on the relative overlapping volume of the parotid gland, it might be different for a specific margin. The mean dose of a more caudal located gland will be larger than a more cranial situated gland.

The relation between the NTCP, calculated using data of Roesink et al. (2001), and the margin is approximately linear (Fig. 4.5 a). This can be explained by the fact that the slope of the NTCP curve is relatively smooth. The NTCP curve of Eisbruch et al. (1998) is, however, steeper and has a lower TD$_{50}$ (28.4 Gy) compared to the data of Roesink et al. (2001). Therefore, the NTCP will increase faster with increasing dose compared to the NTCP values calculated for the data of Roesink et al. (2001).

The choice of a higher resolution of the fluence matrix might improve the steepness of the dose gradient between the parotid glands and the PTVs and therefore reduce the dose to the parotid glands. This will be investigated in the near future. However, since the parotid glands are adjacent to the lymph node containing region, it is anticipated that they will still receive a substantial dose.

The use of less than seven beams for the IMRT treatment might reduce the complexity of the IMRT plans. Less beams might however result, in less homogeneity in the target volumes. Since the number of beams was not a optimization parameter in this paper, a number of beams was chosen with acceptable dose homogeneity in the target volumes. A detailed investigation of the effect of the number of beams on the dose distribution will be reported in the near future.

Accurate delineation of the target volumes is important when using IMRT, since the target volumes and OARs are adjacent to each other and a high dose is delivered to the target volumes. In this study we used CT images for the delineations of the volumes. Other imaging modalities such as Magnetic Resonance Imaging (MRI) might improve the delineation of various structures. MRI has, however, the disadvantage of lack of electron density information, which is important for an accurate treatment planning. In order to improve the delineation process CT-MRI matching (Rasch et al., 1997) might be used, since this allows the simultaneous use of both image modalities.

With the currently available positioning equipment it is possible to achieve a standard deviation of the systematic and the random error of 2 mm or less for head and neck treatment techniques (Hurkmans et al., 2001b; De Boer et al., 2001). With the use of correction protocols, the systematic error can be reduced to 1 mm.
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(De Boer et al., 2001). Although it is often mentioned that accurate patient positioning during the treatment sessions is of crucial importance, margins which take into account the systematic and random errors, are not always explicitly stated in literature. For head and neck cases van Dieren et al. (2000), Eisbruch et al. (1998) and Hunt et al. (2001) used a margin 5, 5 and 10 mm respectively. Using our conventional position verification tools, where anatomical structures are matched using portal images, a margin of 6 mm will be used for head and neck patients. In order to reduce the margin, and thus reduce the dose to the parotid glands, the patient position has to be more accurate. Using stereotactic immobilization systems instead of the conventionally used head masks might improve the positioning accuracy during the treatment. Stereotactic immobilization systems are however usually patient unfriendly. Using dental casts the immobilization might also be improved, this type of immobilization can however not be used for all patients. At our department implanted gold markers (Nederveen et al., 2000, 2001a) are used for daily position verification of the prostate and will eventually be used for online position verification. The same approach will be used for the position verification for head and neck cases. The advantage of the use of markers compared to the matching of anatomical structures is that the automatic detection of the gold markers is accurate and fast. Especially for complex IMRT plans with seven different beam angles, matching of anatomical structures will be more difficult compared to the position verification using gold markers. Two orthogonal fields might be added for position verification purposes. The adding of extra fields for position verification is however in contradiction with the use of IMRT. Using the gold markers for position verification it might be possible to reduce the margin to 3 mm. As has been shown in this study this may result in a NTCP reduction of approximately 20 %.

4.5 Conclusion

The mean dose to the parotid gland decreased when smaller margins are applied to the CTV for the IMRT treatment of the oropharynx. Reducing the margin with 1 mm results in an decrease of the mean parotid dose by approximately 1.3 Gy. Therefore, more accurate patient positioning, resulting in smaller margins, results in a lower NTCP for xerostomia. For a fixed margin the dose to the parotid glands can be reduced, using a more optimal dose constraint set for the parotid glands. The parotid glands, however, will receive a substantial dose and eventually a compromise has to be made between the dose in the lymph node containing region and the dose to the parotid gland.