Summary

In this thesis, intensity-modulated radiotherapy is applied to the irradiation of breast and oropharyngeal cancer. Furthermore, interfraction and intrafraction motions are studied for head-and-neck cancer to further improve the treatment. In the following paragraphs the results are summarized per chapter.

In chapter 2 an IMRT breast technique is developed taking into account the complex three-dimensional geometry of the breast. The aim was to achieve dose homogeneity throughout the entire breast. The IMRT technique was based on the division of the tangential fields in four multi-leaf collimator shaped segments. The shape of these segments was obtained from an equivalent path length map of the irradiated volume. Approximately 88% of the dose was delivered by two open fields covering the whole treated volume. In a planning study including 5 patients, the dose homogeneity improved for the IMRT technique was compared with the conventional technique. The dose homogeneity in the PTV was 9.0% (range 6.4–11.4%) for the conventional and 7.6% (range 6.5–10.3%) for the IMRT technique. The mean lung dose was reduced for the IMRT technique by approximately 10% compared with the conventional technique. Beside the improvements in dose homogeneity and reduction in lung dose, the IMRT technique creates the possibility to improve the field matching in the case of irradiation of the breast and lymph nodes using multiple fields. The new breast irradiation technique has recently been clinically introduced.

In chapter 3 a segmental intensity-modulated radiotherapy technique for the treatment of oropharyngeal cancer was developed. The aim was to deliver three different dose levels simultaneously: one to the lymph nodes (54 Gy), one to the CTV of the primary tumor (66 Gy) and one to the GTV of the primary tumor (69 Gy). The relation between the quality of a treatment plan and the number of beams in combination with the number of segments was investigated in order to obtain a clinically acceptable and deliverable plan. The dose distribution was therefore optimized using beam geometries consisting of 3, 5, 7 and 9 equiangular beams. The optimization procedure resulted in an optimized intensity map for each beam. The optimized intensity map was divided in equidistant levels (5, 7, 10 or 15), in
order to vary the number of segments. The dose homogeneity within the target volumes improved when the total number of segments increased and reached a saturation level at approximately 150 segments. Seven beams were sufficient to achieve the saturation level for dose homogeneity. The mean dose to the parotid glands depended on the beam geometry and tumor location and did not depend on the number of segments.

In chapter 4 the sparing of the parotid glands during the irradiation of oropharyngeal cancer was further investigated. For three different IMRT strategies the effect of reduction of positioning margins was investigated. Margins of 0, 3, 6 and 9 mm were therefore applied to the CTVs in order to obtain four planning target volumes. The analysis of the three IMRT strategies resulted in: (1) an optimal dose distribution in the PTV, (2) an optimal dose distribution in the PTV while sparing the parotid gland and (3) more parotid gland sparing but at the 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 tissue complication probability for xerostomia decreased when smaller margins were applied. Reducing the margin from 6 to 3 mm resulted in a relative NTCP reduction of approximately 20%, showing the benefit of accurate position verification.

In chapter 5 the reliability and toxicity of the use of implanted gold markers for position verification during the irradiation of head-and-neck cancer was investigated. Ten patients with localized head-and-neck tumors received two gold markers in the parapharyngeal region. The acute and late radiation related toxicity were scored prospectively, using common toxicity criteria. The marker location was detected in portal images taken on average during 19 fractions. The inter-marker distance as well as the interfraction motion were determined for all patients. No acute major complications were observed. The gold seeds did not enhance the acute toxicity grade. The markers were visible in all images. A small time trend was observed in the inter-marker distance for three patients. For these patients at least one marker was located in the pharyngeal mucosa or pharyngeal constrictor muscle. Deep-seated gold markers did not show a time trend. The random error of the geometric uncertainties obtained without correction during radiotherapy was 1-2 mm. It was concluded that the use of implanted gold markers for position verification during radiotherapy of head-and-neck patients seems feasible. To avoid any chance of migration, markers should be placed in deep muscular compartments.

In chapter 6 the intrafraction motions of the larynx were investigated during radiotherapy. The larynx is a rather mobile organ in the head-and-neck region, and motion may occur due to swallowing, breathing, or movement of the tongue. De-
pending on the magnitude, duration and incidence, these motions may have clinical consequences for the choice of margins around the clinical target volume. The intrafraction motions of the larynx were visualized using an a-Si flat panel imager. Images were obtained every 200 ms, resulting in a movie of images for each beam. Movies were obtained during 79% of the total number of radiotherapy fractions. The total duration of swallowing was on average 0.45% (range 0.0 – 1.5%) of the total irradiation time. Deviations of motions other than swallowing ranged from 0.3 to 11.5 mm. Some of these motions were sudden, while others were probably related to breathing, because the frequency of these motions was 8 – 20 per minute. Due to the low incidence it is not necessary to apply an internal margin to take into account displacements due to swallowing. A margin should however be applied for other more frequent motions.

Two different segmental IMRT techniques have been developed in this thesis for respectively irradiation of the breast and the oropharynx. Both techniques have been implemented clinically. Various other improvements can be applied as have been discussed in chapter 7. Part of them, concerning position verification for head-and-neck cancer, have been investigated in this thesis.