Fast and robust automated segmentation of the cervix-uterus structure in CT-images driven by patient-specific motion-models

Innovation/Impact: To the best of our knowledge we developed the first automated segmentation (AS) method for cervix-uterus in CT-images that produces fast and robust results.

Introduction: For cervical cancer patients, online treatment adaptation results in better organ-at-risk sparing than population-based margin strategies. Treatment adaptation can be accomplished by selecting, based on a daily acquired in-room CT-scan, the best plan-of-the-day, from an individualized library of plans. Fast and robust automated segmentation of the cervix-uterus in the CT-images with minimal user interaction is essential for the plan selection strategy. Current AS methods for pelvic organs use statistical shape models to initialize and guide the segmentation process. However, statistical models are limited by the requirement of a large training set and are unsuitable for cervix-uterus due to the large inter and intra-patient shape variation. The aim of this work was to develop and test a novel intra-patient AS method of the cervix-uterus structure in CT-images.

Methods and materials: An AS method was developed that adapts an initial surface of the cervix-uterus to new image data. The novel idea was to use patient-specific motion models derived from only two CT-scans (full and empty bladder) instead of a statistical model. To initialize the surface we used a 3D patient-specific cervix-uterus motion-model predicting the shape and position of cervix-uterus based on bladder volume and a 1D model predicting the bladder volume based on a manually identified bladder top. The initialized surface was translated based on the center of mass of implanted markers and was adapted to the new image by minimizing the sum of external and internal energy. The external energy attracts the model to prominent image edges and the internal energy penalizes shape deviations from the model. The method was tested on 13 patients that had 9-10 variable bladder filling CT-scans acquired at pretreatment and after 40 Gy. For each patient, two pretreatment CT-scans (full and empty bladder) were used for model construction and the remaining 7-8 CT-scans were used for testing. The error in predicting the bladder volume was -3±70 ml. The cervix-uterus surface was closely initialized; the overlap between the manually delineated and the initialized cervix-uterus was 82±7% for pretreatment and 71±11% for the after 40 Gy scans. The automatic adaptation of the initialized structure to boundaries in the image increased the overlap to 87±3% for pretreatment and 80±13% for after 40 Gy (examples in Figure 1). The automated segmentation method took on average 2±0.5 minutes for each CT-scan.

Results: Marking the bladder top and the markers required minimal user intervention (below 1 minute for each CT-scan). The error in predicting the bladder volume was -3±70 ml. The cervix-uterus surface was closely initialized; the overlap between the manually delineated and the initialized cervix-uterus was 82±7% for pretreatment and 71±11% for the after 40 Gy scans. The automatic adaptation of the initialized structure to boundaries in the image increased the overlap to 87±3% for pretreatment and 80±13% for after 40 Gy (examples in Figure 1). The automated segmentation method took on average 2±0.5 minutes for each CT-scan.

Conclusion: A fast and robust automated segmentation method of cervix-uterus structure in CT-images was developed and tested. Our method is a useful tool that could support image guided online adapted radiotherapy for cervical cancer patients.