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Metal artifact management in volumetric modulated arc therapy for head and neck treatment

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Introduction

In computed tomography (CT) images, discrepancy caused by prosthetic materials between the CT numbers in the reconstructed image and the true attenuation coefficients of the object affect negatively the radiotherapy (RT) treatment planning. Metallic materials generate artefacts due to both "photon starvation" and "beam hardening" along the X-ray beam path.
RT in head-neck district includes, in most cases, oral cavity mucosa in the radiation fields. The presence of non-removable metal dental restoration materials (dental fillings, crowns, bridges and implants) reduce the precision of target volumes (PTV) and organ at risk (OAR) contouring and, also, the dose calculation accuracy.

Aim

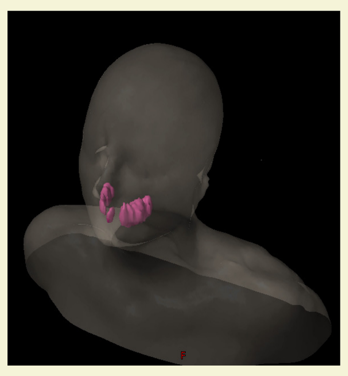
The clinical impact of a new automatic tool named segment high density artifact (SHDA-tool) was investigated to delineate the high-z material in patients treated for head and neck cancer with volumetric modulated arc therapy (VMAT) technique.

Methods

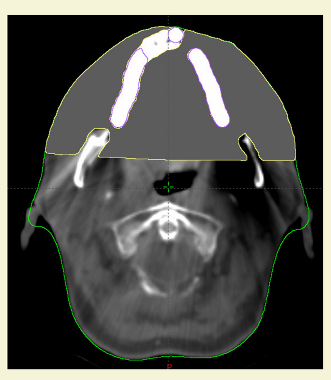
50 VMAT plans were analyzed for head and neck cancer district in patients with nonremovable metal dental restoration (i.e. crowns, implants) generating artifacts, near and/or inside high risk PTV.
Dose distribution is calculated with Acuros-XB algorithm (Eclipse v.13.7, Varian Med.Sys.). In case of electron density higher than 3.00g/cm^3, this algorithm does not automatically assign density to HU. However it is necessary to define this correlation for all patient CT-images voxels, also in high z-materials. Acuros-XB calculations are prevented until material is assigned, also in that region.
Two set of planning-CT images were obtained for each patient: the first one with automatic structure definition and the second one with manual structure definition.

AUTOMATIC CONTOURED STRUCTURE

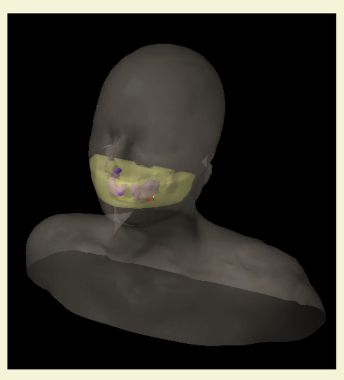
In this set, SHDA-tool was used to automatically create an high resolution segment structure that covers all image pixels where mass density is higher than 3.000 g/cm3. It adds a 1mm margin around the structure to ensure even the smallest artifacts are covered. To this structure was assigned Titanium Alloy density (4.42g/cm^3). No density correction was made in other artifacts area caused by implants in soft tissue regions (i.e. oral cavity) near or inside PTV.



MANUAL CONTOURED STRUCTURES



Both prosthetic materials and soft tissue regions with artifacts were manually contoured. To those structures were assigned Titanium Alloy and muscle-skeletal (1.05 g/cm3) mass density respectively. Where prosthesis are inserted, the volume has been contoured along dental arch using circular brush with 0,8 cm diameter. Soft tissue regions are drawn on images with artifact adding one slice above and one below the prosthesis teeth and internally expanding until the mandible.



VMAT plan was optimized, for each patient, following clinic protocols of our Department. At the end of the optimization process, dose distributions were calculated on both CT sets (not changing MU numbers). From the two plans some relevant clinical parameter were analyzed from dose-volume histogram (DVH). All OAR were contoured by physician; while mucosae near implant are the first 5 mm near interface. Conformity index and target volume receiving 105% of dose prescription were studied for target. Maximum dose and mean dose were analyzed for mucosae, mucosae near implants interface and parotids, while for mandible, only maximum dose was analyzed. Maximum dose was defined as the dose received from 0.03 cc^3.

Results

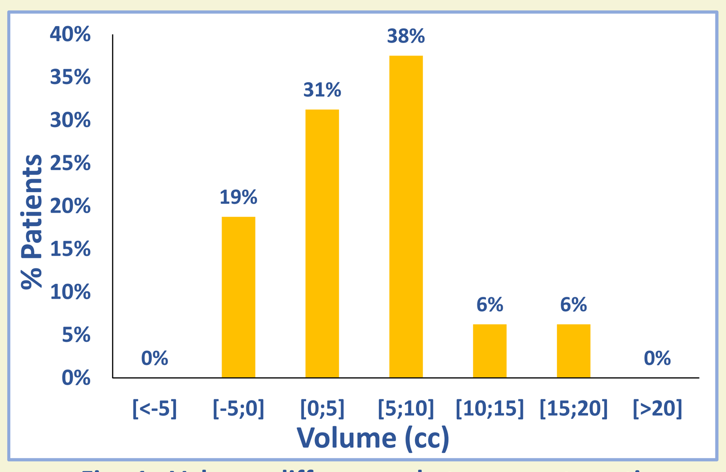


Fig. 1: Volume differences between automatic and manual structures.

Absolute volume difference between automatically and manual contoured regions (where metals are present) is reported in figure 1.
Automatic-structure volume is bigger than the manual one in 81% of patients.
The mean of volume differences is limited and is equal to 6.7cc [-4÷20cc].

Two parameters have been chosen to analyze PTV dose coverture.

- The first one is the conformity index parameter (CI), calculated as the volume enclosed by the prescription isodose surface divided by the target volume. Figure 2 shows the percentage difference of CI calculated for the two plan for each patient. In over 85% of patient that difference in CI was less than 5%.

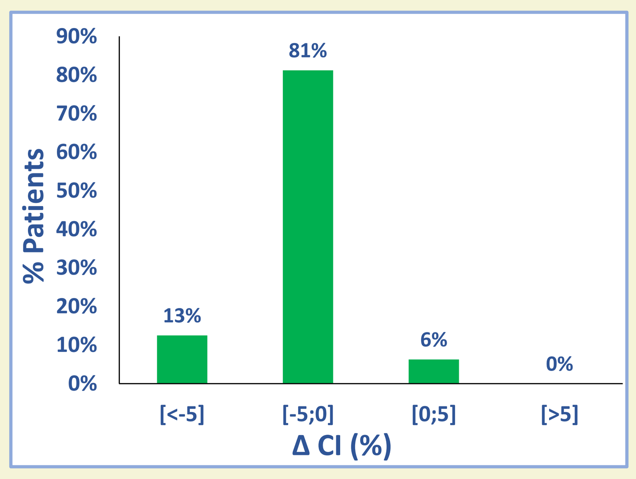


Fig. 2: Differences between Conformity Index for two set of planning-CT.

- The second one is the volume of PTV that receives at least 105% of dose prescription. At least 90% of cases have differences lesser than 1cc, for this parameter (Fig.3).

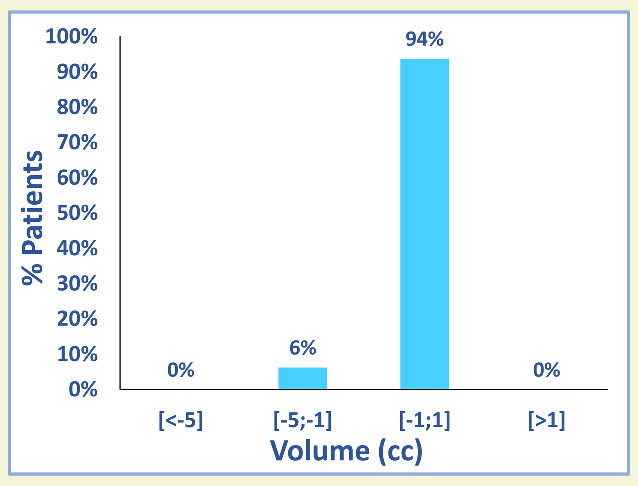


Fig. 3: Differences between the PTV volume, for two set of planning-CT, that receive 105% of dose prescription (V105%).

For OAR small differences were observed in maximum dose. Figure 4 shows that the differences are less than 1Gy in more than 75% of the patients.
Differences bigger than 2Gy are observed in 12% of cases and only in the near implant area and not in other OARs.
Also parotids and mucosae mean dose, spinal cord maximum dose were analyzed but there are no significant differences.

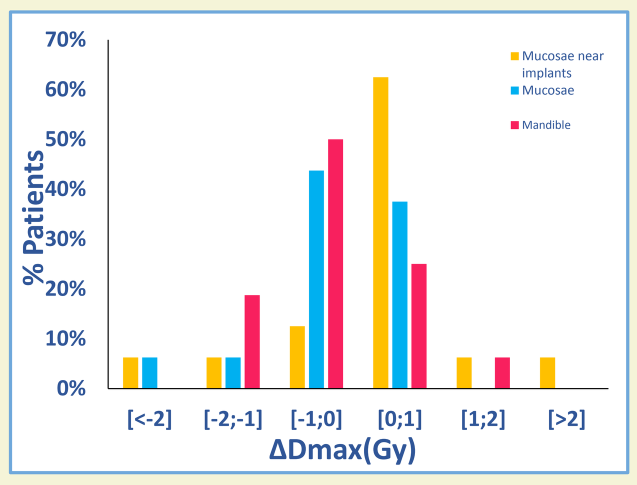


Fig. 4: Differences in maximum dose between the mucosae near implants, mucosae and mandible for two set of planning-CT.

Fig. 5a: Planning CT-automatic set.

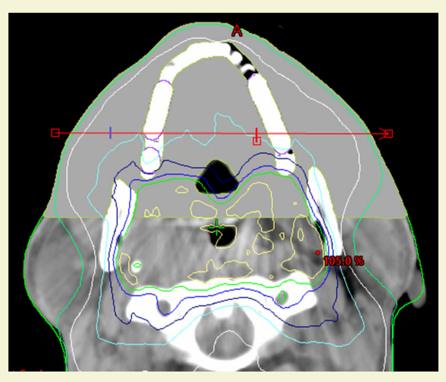


Fig. 5b: Planning CT-manual set.

Figures 5a,b,c show an example of dose profiles for one of the selected patients. The difference between the profiles is found mainly in the area of artifacts.

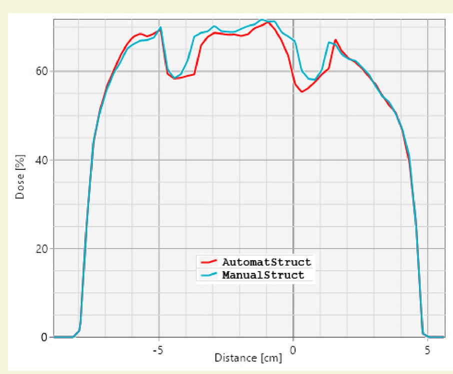


Fig. 5c: Compare dose profile.

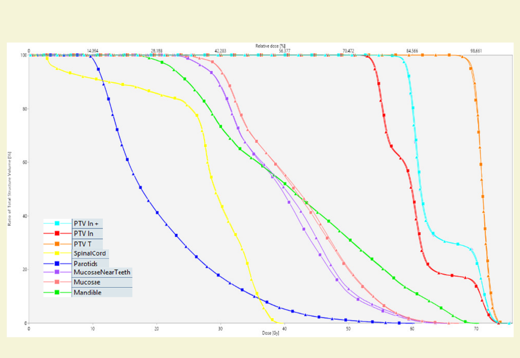


Fig. 5d: DVH compare.

Figure 5d shows the Dose Volume Histogram for the same patient. There are no significant differences between two CT planning set.

Conclusions

As expected, the main differences were observed in the interface area between implants and the mucosae of the oral cavity. This is probably due to the low contouring accuracy of the real prosthesis. Overall the differences in dose distribution between the two methods, for each patient, were small and not clinically relevant.
It was decided to introduce the SHDA tool in our planning instead of manual contouring structures. Furthermore, this is more time efficient.
To improve PTVs and OARs contouring we are going to evaluate on of the recently commercial algorithm for CT-image reconstruction.

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