Influence of Oral Contrast Agent On Dose Calculation of Radiotherapy Treatment Planning for Pancreatic Cancer a Multi-Factor Systematic Analysis Based On 3D Conformal Radiation Therapy and Volumetric Modulated Arc Therapy

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Purpose
Using positive oral contrast in gastrointestinal CT scan could improve the profile quality of bowel wall display structure and assist the delineation for pancreatic cancer radiotherapy. However the problem is contrast medium changed the electron density of content and would cause the dose calculation error when planning. In our study, we investigate the dosimetric influence of oral contrast medium used for pancreatic cancer radiotherapy treatment planning, as well as the influence intensity correlated to different levels of contrast density and different radiation techniques.

Methods
Firstly we designed a virtual phantom in Monaco system to simulate the photon beam passing through the contrast volumes with different Hounsfield Unite(HU) value from different angles. Secondly 10 patients with locally advanced pancreatic cancer and no remote metastasis were enrolled in our study. Candidates were given 250mL of diluted solution consisting 3% iopamidol 15mins before CT scanning. Target volumes, normal tissue and gastrointestinal contrast volume were countered with precise, using threshold auto-counter function with an appropriate Hounsfield Unit (HU)>80. In our study, we simulated 4 branches of plans as 5-beam conformal radiotherapy (5b-CRT), 7-beam conformal radiotherapy (7b-CRT), 9-beam conformal radiotherapy (9b-CRT), and 2-arc volumetric modulated arc therapy (VMAT) for each patient. For each plan, 8 QA-plans were parallel designed keeping all parameters the same except the contrast HU values were forced filled with 8 bulks of HU from OHU(ED=1.0) to 1000HU (ED=1.54). Dose distribution of individual plans were compiled and compared. Define the planned dose with reassigned HU=0 as the baseline of non-enhanced CT. Dosimetric equivalence verification was done before analyzing the deviation in detail.

Results
Figure 1 represented the dose differences at the central point volume of phantom with increasing enhanced HU values for individual energy beams and different incident angles. The difference ascended as the enhanced HU increased consequently. High energy group had relatively small dose difference compared with low energy group(p=0.0034). For 6MV, the calculation uncertainty and grid. For the normal tissue, the difference was also smaller than 1.5±1.5%, while the contrast-involved organs like duodenum, stomach and intestine showed a relatively higher difference than non-contrast involved organs like the spinal cord, kidney. Also we observed a non-significant relatively lower PDD/PV of VMAT plan than 5b-CRT plan. Figure 3 revealed the dose difference of different techniques with different contrast levels. 5b-CRT branch had the most serious underestimation, while VMAT branch had the most slight influence caused by contrast HU increase. The averaged percentage difference of Dmean, D95 and D5 of GTV, CTV and PTV were all smaller than 1% when HU enhancement is smaller than 500. In normal tissue, the percentage difference was relatively larger than in targets. The percentage difference of VMAT branch had less impact from HU enhancement level compared with that of 5b-CRT branch. The impact difference between 7b-CRT and 9b-CRT was not significant.

We also investigated the correlation between contrast enhancement level and the average gamma index passing rate of patients under a criterion of 2mm/2% for different techniques. For 5b-CRT plan, when HU is smaller than 300 the passing rate of target volume is higher than 97%. For VMAT plan the passing rate could be higher than 97% even the HU reached to 500. It indicated that the contrast enhancement would influence the dose distribution much smoother with beam numbers increase. The cold point was mainly focused in the high dose volume. More specifically, the difference was much larger at the interface between contrast volume and intestinal wall. The failure points were all in and around the high dose region at the interface.

Conclusion
Our study proved that the contrast would introduce dosimetric error that could underestimate the actual dose delivered to target volume and normal gastrointestinal tract compared with daily irradiation without contrast, but the dose difference is clinically negligible if the enhanced electron density is limited in a reasonable intervale. intensity modulation treatment like VMAT is less influenced compared to traditional conformal RT. A relatively confidential range of enhancement level is average HU<300 for conformal RT, and HU<500 for VMAT. Use of larger than confidential level must be strictly evaluated before clinical treatment.