The effect of contrast agents on dose calculation in conformal radiotherapy planning

using computed tomography for tumors at different anatomical regions

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Abstract

The purpose of this study was to evaluate the effect of contrast agents on dose calculation in 3-Dimensional Conformal Radiotherapy (3D-CRT) for brain, thorax and upper abdomen region in Ramathibodi hospital. Five, six and four cancer patients for brain, thorax and upper abdomen region respectively were studied for retrospective study. Each patient took two sets of CT images in the same position before and after IV contrast agent injection. To avoid the movement artifact, the CT images of thorax and upper abdomen regions of without-contrast agent were imitated by overriding the density to the organs or regions using the density obtained from the original without-contrast agent CT images. The approved plan by a radiation oncologist was copied to both with- and without-contrast agent CT images. Both of the plans used the same monitor unit. The doses calculated from two plans were compared with regard to tumor volume and organs at risk volume. The paired sample t-test and gamma evaluation were used to evaluate the differences in dose distributions between two plans. The results of doses of tumor volume and organs at risk volume were not significantly different between with - and without-contrast agent CT images for brain, thorax and upper abdomen region ($p > 0.05$), except heart organ in thorax region ($p < 0.05$) but the dose differences were less than 1% compared to dose calculated from without-contrast agent CT images. The number of passed pixel was more than 95% and the gamma value was less than 0.5 for dose distributions compared between two sets of CT images. As a result, using contrast agent at the time of CT simulation dose not significantly affect on dose calculation in 3D-CRT.

Keywords : Conformal radiotherapy, Contrast agent, Treatment planning, Dose calculation

I. INTRODUCTION

Computed tomography (CT) images are primary images for radiotherapy treatment planning because they provide axial images for internal organ information, high image resolution and CT number for being converted to electron density in dose calculation. CT number is very useful for tissue inhomogeneity correction that provides more accurate dose calculation for 3D treatment planning. In 3D treatment planning, using contrast agent during CT scanning improves the accuracy of tumor volume and organs at risk delineation. However for dose calculation, contrast agent will increase x-ray attenuation and mean CT number value to higher electron density tissue. During treatment delivery, contrast agent is not used. Therefore, it causes error of the dose to be irradiated in a patient.

Previous study using phantom showed that contrast agent do effect on dose calculation when used at high concentration and enlarge region (1). But in clinical studies on brain, head and neck, thorax, upper abdomen, pelvis and bladder presented that contrast agent do a little effect on treatment planning because concentration of contrast agent in tissues not too high (2-8). However, those studies are different in many factors such as type of contrast agent, CT simulator, and treatment planning algorithm so their conclusion might not be acceptable for our study.

Therefore, the purpose of this study was to compare mean dose and dose distribution between with- and without-contrast agent in 3-Dimensional Conformal Radiotherapy (3D-CRT) for tumor at brain, thorax and upper abdomen regions treated in Ramathibodi hospital.

II. MATERAIALS AND METHODS

Five, six and four cancer patients for brain, thorax and upper abdomen regions respectively were selected from cancer patients that treated by 3D-CRT, and each patient had to take two sets of CT images in the same position before and after IV contrast agent injection by using CT simulator (Philips, MX 8000 IDT). For with-contrast agent, 50 mL volume of contrast agent (Ultravist 300 mgI/mL) for the brain and 100 mL for another regions was injected at 2.5 rate of injection and starting scan was done with delay time after threshold level (150 HU) at 25 seconds for brain and thorax and 45 seconds for upper abdomen.

Treatment plans approved by a radiation oncologist for 3D conformal technique using Pinnacle3® RTPS, version 7.6C were used in this study. Brain region is the stable anatomical region so the original two sets of CT images (without- and with contrast agent) were used. But thorax and upper abdomen have a problem of internal organ movement due to respiration, so simulating one set of CT images from another set was obtained to eliminate confounding factor such as SSD and patient deformation. In this study, without-contrast agent of thorax and upper abdomen CT images was imitated by overriding the density to the organs or regions using the density obtained from the original without-contrast agent CT images. In order to simulate without contrast agent for thorax and upper abdomen region, density of contrast agent in the regions that uptake contrast agent were overridden by using the density that measured from without contrast agent CT image at the same regions. The first treatment plan for without-contrast agent was performed using the approved plan, and then dose was calculated. A second plan was done

for with- contrast agent in the same plan and same monitor units for individual beam and dose was calculated again.

For data analysis, the dose calculated from two plans was compared with regard to tumor volume and organs at risk volume by paired sample t-test and gamma evaluation. They were used to evaluate the differences in dose distribution between two plans. The criterion of 3% of maximum dose difference and 3 mm distance to agreement were applied to generate the gamma map (9, 10).

III. RESULTS AND DISCUSSION

The comparison of 3D-CRT dose calculation from with and without contrast agents by using percentage of dose difference and paired sample t-test for brain, chest and upper abdomen regions are shown in table 1, 2 and 3, respectively.

From table 1, the percentage of dose difference for tumor volume, left eye, left optic, right eye, right optic, optic chiasm and brain stem are 0% (0.8033),-0.06% (0.3046),-0.13 (0.3399), 0% (0.6657), 0% (0.7040),-0.05% (0.3046) and 0.02% (0.2522), respectively. All results show no difference between with - and without-contrast agent CT images treatment plan, significantly.

From table 2, the percentage of dose difference for tumor volume, spinal cord, left lung, right lung and heart are -0.68% (0.1015), -0.65% (0.0835), -0.33% (0.0771) , -0.46% (0.2875) and -0.77% (0.0366), respectively. The results show no significant difference between with- and without-contrast agent CT images treatment plan for tumor volume, spinal cord, left lung and right lung except heart. Dose different at heart is different between two plans because enhanced CT image has a lot of contrast agent filled in heart with high concentration and enlarge region, so density at heart volume between with- and without-contrast agent CT images treatment plan is more different than other organs.

From table 3, the percentage of dose difference for tumor volume, spinal cord, liver, spleen and right kidney are -0.34% (0.1323), 0% (0.2062), -0.74% (0.2062), -0.50% (0.0742) and -0.51% (0.2465), respectively. All results show no significantly difference between with- and without-contrast agent CT images treatment plan.

Table 1 Comparison of dose calculated from with- and without- contrast agent in 3D-CRT using the percentage of dose difference and paired sample t-test for brain cancer patients (n = 5)

	Mean normalized dose ± SD (%)		% dose difference	p- value
	Without contrast	With contrast		
Tumor volume	102.07±3.07	102.07±3-06	0.00	0.8033
Left eye	12.66±11.60	12.64±11.58	-0.16	0.3046
Left optic	31.97±34.60	31.93±34.53	-0.13	0.3399
Right eye	19.44±16.62	19.44±16.61	0.00	0.6657
Right optic	26.75±27.61	26.75±27.59	0.00	0.7040
Optic chiasm	60±35.62	59.97±35.61	-0.05	0.3046
Brain stem	43.68±41.03	43.69±41.05	0.02	0.2522

Table 2 Comparison of dose calculated from with- and without-contrast agents CT images by 3D-CRT using the percentage of dose difference and paired sample t-test for thorax cancer patients (n = 6)

	Mean normalized dose ± SD (%) Without contrast	With contrast	% dose difference	p- value
Tumor volume	103.14±4.75	102.44±3.97	-0.68	0.1015
Spinal cord	36.71±5.2	36.47±5.37	-0.65	0.0835
Left lung	17.93±8.21	17.87±8.18	-0.33	0.0771
Right lung	46.15±22.22	45.94±22.03	-0.46	0.2875
Heart	42.92±16.53	42.59±16.65	-0.77	0.0366

Table 3 Comparison of dose calculated from with- and without-contrast agents CT images by 3D-CRT using the percentage of dose difference and paired sample t-test for upper abdomen cancer patients (n =4)

	Mean normalized dose ± SD (%) Without contrast	With contrast	% dose difference	p- value
Tumor volume	99.96±0.44	99.62±0.36	-0.34	0.1323
Spinal cord	44.98±30.25	44.98±30.18	0.00	0.2062
Liver	24.41±30.27	24.23±30.01	-0.74	0.2602
Spleen	17.84±11.26	17.75±11.20	-0.50	0.0742
Right kidney	19.7±30.93	19.6±30.8	-0.51	0.2465

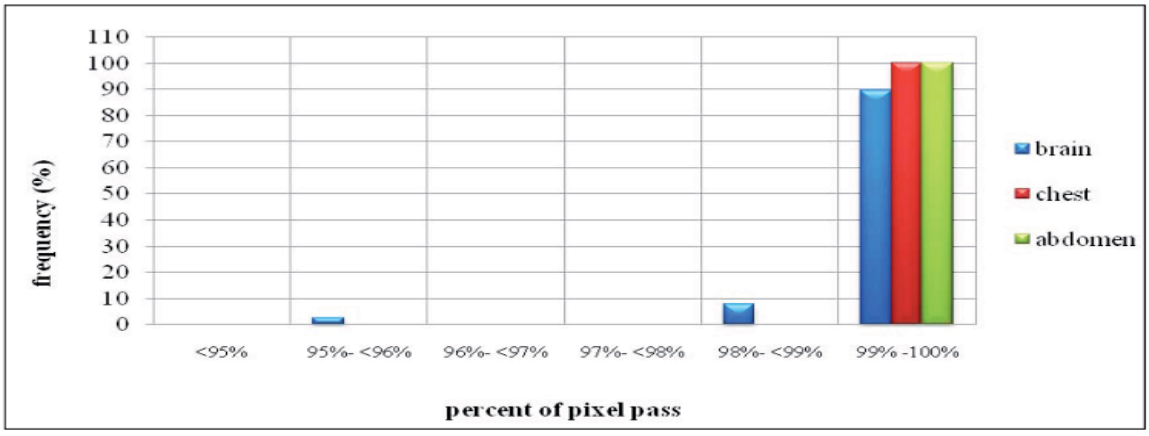

Figure 1 Histogram of the percentage of passed pixels of the dose distributions for brain, thorax, and upper abdomen regions.

Histogram in figure 1 shows the summary results from gamma evaluation for three parts of cancer patients. They all show good agreement which means the number of pixel passed more than 95%. In brain region, it shows the poorest results when compared with other regions because brain region used the original without- contrast agent CT images while others used the simulated without-contrast agent CT images. The advantage of using simulated CT images is to eliminate confounding factors such as patient deformation and source to skin distance variation. Therefore thorax and upper

abdomen regions give good results more than brain region.

The results shown are not significantly different between with- and without-CT contrast agent plans. The benefits of using with-contrast agent CT images in dose calculation are, first reducing time in process of registration and image-fusion between with- and without-contrast agent CT images. And secondly, reducing space to store sets of images in treatment planning. That might not support several sets of images.

Shibamoto et al (6) showed a difference between with- and without- contrast agent plan in upper abdomen which differs from this study. Because two original CT image sets (with- and without-contrast agent) were used as a result, SSD or patient deformation were different between two image sets. However our two CT image sets had the same condition using overriding density technique to eliminate the confounding factors. Therefore there is only one factor that affects in our results, contrast agent.

IV. CONCLUSIONS

Using contrast agent at the time of CT simulation dose not significantly affect on dose calculation in 3D- CRT for tumors at the brain, thorax, and upper abdomen regions.

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