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Comparison of Dose Distribution in Clinical Planning and Dose Plan Using the Concept of Definite Target Volume in Stereotactic Radiotherapy Techniques

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ABSTRACT

Introduction: To implement the newly introduced concept volume of Definite Target Volume (DTV) and compare the distribution and dose-escalation in the DTV and clinical plans.

Material and Methods: We used seven samples of hepatocellular carcinoma (HCC) and three cervix tumour plans. DTV is determined through occupancy probability and margin contraction. This margin reduces the Clinical Target Volume (CTV) to obtain the DTV volume. DTV optimisation was achieved by giving the maximum dose to the target volume and limiting the organ at risk (OAR) by constraint.

Results: The DTV volume is obtained with a range of 60.8–913.9 cc for HCC and 2.4–22.9 cc for the cervix tumour. In HCC, the average D_{max} at DTV volume increased to 124.98 ± 29.02, whereas the average D_{mean} increased to 105.36% ± 2.66% for the Planning Target Volume-crop (PTV-crop). For cervix tumour cases, the highest dose on DTV volume reached 138.49%, and the average D_{max} at DTV volume increased to 116.80% ± 13.19%. In addition, the average D_{mean} increased to 101.89% ± 5.58% for the PTV-crop. A larger dose delivered at the DTV will be associated with an increase in OAR. The dose increase of OAR-HCC is 106.93% ± 5.57%, and OAR-cervix is 101.18% ± 1.87%.

Conclusion: The larger margins generate smaller DTV volumes or *vice versa*. The dose to target DTV has increased considerably, but dose increases to PTV-crop and OAR are still within clinically acceptable levels.

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Introduction

The International Commission on Radiation Units and Measurements (ICRU) has issued several reports on external photon radiotherapy prescription, recording, and reporting activities. The ICRU report is expected to become a widely-applied recommendation to increase radiotherapy implementation activities [1]. In radiotherapy planning, based on the ICRU-62 definition and margin formula, the goal is to ensure the target tissue receives the correct prescribed dose, including the dosimetric effects of spatial uncertainty [2]. Hopefully, by knowing the uncertainty of PTV, the prescribed dose of tumour can be achieved despite of its spatial uncertainty [3].

Random errors are introduced in the daily setup process combined with variations in target position caused by organ movement [4]. In many studies at multiple tumour sites, the uncertainty involved in delineating the target volume will have a more significant impact than the error in all other steps because of inconsistencies in the treatment process. Delineation error and other systematic errors must be accommodated with appropriate margins at the treatment preparation stage. They will be spread across the complete fractionation schedule [4,5]. The margin considers systematic geometry uncertainty (treatment preparation) and random geometry uncertainty (setup). Planning organ at risk volumes (PRV) can be determined to improve prediction on volume-dose and help secure critical organs (OAR), resulting in safer doses [6].

In the mid-1990s, a new technique in radiotherapy to treat cancer was discovered that could provide the potential for greater local control, namely Stereotactic Body Radiotherapy (SBRT) [7]. SBRT is one of the methods in radiotherapy using two to five fractions of radiation that accurately follows the shape of the patient's tumour. This method provides an alternative option that is more effective, non-invasive and can improve therapeutic treatment with small tumours. This technique aims to overcome the inherent radio resistance of the tumour using a higher radiobiological

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equivalent dose. The basis of SBRT is a significant reduction in PTV size. The resulting volume reduction allows for much higher dose increases when compared to dosing with more traditional radiotherapy techniques, such as three-dimensional conformal radiation therapy (3DCRT) [7,8]. SBRT considers many things, including respiratory movement, daily targeting of tumours using high-resolution image-guided, appropriate patient immobilisation, and advanced treatment planning techniques to produce sharp dose reductions between tumour and normal tissue [9]. However, there are concerns that damage to normal tissue will limit the amount of radiation delivered to the tumour [10]. This must be supported by radiotherapy techniques with high precision to minimise errors. Patient setup errors in treatment can be minimised by stereotactic positioning and image guidance [7].

The main advantages of SBRT are the accuracy of its treatment and the potential hypo fractionated treatment [11]. However, it is possible to have a hotspot area from this advantage because a small fraction will cause a high dose. Research by Watkins et al. [12] proposed a new target volume, namely Define Target Volume (DTV). DTV may have a high probability of locating the targeted tissue is. In the ideal case, DTV has a spatial region where the occupancy probability is unity, meaning that the likelihood of OAR or PRV overlapping with DTV is close to zero as explained in Figure. 1. Dose optimisation to DTV represents maximally high dose delivery and is limited by dose constraint surrounding healthy tissue. It is hoped that this concept can DTV in radiation therapy or be used as an alternative in clinical planning [12]. In this study, we have implemented the DTV concept and compared it to clinical planning in our institution for *hepatocellular carcinoma* (HCC) and cervix tumour cases.

Materials and Methods

Patient selection

Patient planning samples were selected by collecting medical record data at the Department of Radiation Oncology, Cipto Mangunkusumo General Hospital Jakarta. Patients chosen for samples had HCC and cervix cases using the SBRT technique. Ten patients met the research criteria, with details seven for HCC and three for cervix tumour cases. The criteria are regarding the presence of organ movement and the difference in the dimensions of the two tumours. The case site was selected based on the conditions in which both cases had significant organ movement. For the cervix, deformation is a major issue while for HCC peristaltic and breathing-induced motion is dominant. Another reason is because HCC has a large volume and the cervix tends to be smaller. The number of patients was obtained from the availability of clinical planning for cases of HCC and cervical tumours. Data and planning using treatment planning systems (TPS) Eclipse and shifting data obtained from offline reviews based on On-Board Imaging (OBI) verification results when treatment was carried out.

Defining the Definite Target Volume

DTV is determined through occupancy probability and margin contraction. It is identified as a volume with a high occupancy probability of the target tissue. The Clinical Target Volume (CTV)-to-DTV design margin was obtained by considering random (σ) and systematic (Σ) spatial uncertainties. The margin reduces the CTV to derive the DTV volume [12].

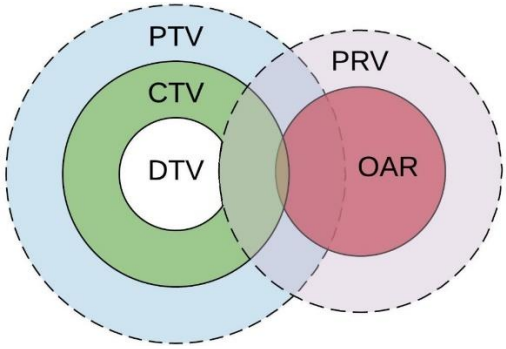

Figure 1. DTV is shown as a contraction of the obtained CTV by margin as well as PRV [12].

The results of the position shift data will be processed, and the results of individual random errors ($\sigma_{individual}$) and individual systematic errors ($m_{individual}$) in each patient on each axis are obtained. The result, is, then, calculated to get random setup error (σ_{set-up}) and systematic setup error (Σ_{set-up}) [13].

$$\sigma_{individual} = \sqrt{\frac{(\Delta_1 - \bar{\Delta})^2 + (\Delta_2 - \bar{\Delta})^2 + \ldots + (\Delta_i - \bar{\Delta})^2}{(n-1)}} \quad (1)$$

$$m_{individual} = \frac{\Delta_1 + \Delta_2 + \Delta_3 + \ldots + \Delta_i}{n} \quad (2)$$

The $\sigma_{individual}$ is obtained by calculating the standard deviation of the differences of each sample from position shift data and then calculating the average so that a random population error (σ_{set-up}) will be obtained on each axis. Shift position in each fraction (i) is symbolized by Δ_i and n is the number of fractions given to the patient. While $m_{individual}$ is the sum of all the shifts obtained from each fraction then divided by the number of given fractions.

In the HCC case, to get the total setup error of the three axes ($\sigma_{set-up\,(Total)}$), the σ_{set-up} on each axis is calculated using Eq. (4) with LL means laterolateral, AP means anterior-posterior, and CC means craniocaudal. Random setup error calculated from $\sigma_{individual}$ and divided by the number of patients (N). Using the organ's movement factor around the target, a random error (σ) will be obtained [13].

$$\sigma_{set-up} = \frac{\sigma_1 + \sigma_2 + \sigma_3 + \ldots + \sigma_i}{N} \quad (3)$$

$$\sigma_{set-up\,(Total)} = \sqrt{\sigma_{setup\,(LL)}{}^2 + \sigma_{setup\,(CC)}{}^2 + \sigma_{setup\,(AP)}{}^2} \quad (4)$$

$$\sigma = \sqrt{{\sigma_{set-up}}^2 + {\sigma_{organ\ motion}}^2} \quad (5)$$

In this study, the value of organ movement was obtained from research from Gong et al. for HCC and Jensen et al. for cervix tumour which was considered to be in accordance with the research criteria. By determining the movement of the diaphragm in the case of HCC, the average shift as measured is 1.39 cm for 3DCT and 4DCT [14]. In the cervix tumour, the uterus cervix was measured manually on the CT-scan plan to calculate the individual Internal Target Volume (ITV) margins (the distance from the anterior-posterior borders). Therefore, the median ITV margin associated with the uterus and cervix is 1.2 cm [15].

Individual systematic error ($m_{individual}$) is obtained by calculating the average deviation of each position shift data in each individual. Then the population mean systematic setup error (M_{pop}) can be estimated and the population systematic setup error (Σ_{set-up}) to obtain the setup error on each axis. The individual systematic error in a given patient is symbolled by m_n and N is the number of patients in the analyzed group. Eq. (8) will get the total systematic setup error ($\Sigma_{set-up\ (Total)}$) [13,16].

$$M_{population} = \frac{m_1+m_2+m_3+\ldots+m_i}{N} \quad (6)$$

$$\Sigma_{set-up} = \sqrt{\frac{(m_1 - M_{pop})^2 + (m_2 - M_{pop})^2 + \ldots + (m_i - M_{pop})^2}{N}} \quad (7)$$

$$\Sigma_{set-up\ (Total)} = \sqrt{{\Sigma_{set-up\ (LL)}}^2 + {\Sigma_{set-up\ (CC)}}^2 + {\Sigma_{set-up\ (AP)}}^2} \quad (8)$$

$$\Sigma = \sqrt{{\Sigma_{set-up}}^2 + {\Sigma_{delineation}}^2} \quad (9)$$

The data obtained from the measurements are then calculated to obtain the margin formulated by van Herk. The margin (M) will reduce the CTV volume to get the DTV volume [16,12].

$$M = 0.7\sigma + 2.5\Sigma \quad (10)$$

Definition of Target Volume Optimisation

Optimisation of DTV is conducted by exploring the maximum DTV dose by limiting the dose to the OAR constraint. DTV optimisation is obtained by considering several DTV-related OARs. The combined OAR will be added with a margin to derive PRV. However, if the PRV with the additional margin is insufficient to touch the DTV, the PRV can be ignored. The OAR dose will be limited by the dose of each organ constraint [12].

Comparison of the Results of DTV Planning and Clinical Planning

Planning DTV uses SBRT because it uses hypofractionated and high doses. Target in clinical planning is generally optimised in the PTV area. Meanwhile, the DTV concept will be modified to have two optimisation targets, namely DTV and PTV-crop. PTV-crop is PTV volume that has been cut from the DTV volume by adding a small margin as described in Figure 2. Planning that uses two targets, DTV and PTV-crop, is then called DTV planning. DTV planning is done by re-planning the clinical plan by no longer targeting optimisation to the PTV area. Target optimisation will be changed and delivered to the DTV and PTV-crop volumes. The two plans then compared the doses in target volume such as PTV, PTV-crop, and DTV, also the OAR in each case.

Results

Position shift data collected from TPS Eclipse contains data for each shift on the laterolateral (LL), craniocaudal (CC), and anterior-posterior (AP) axes in each fraction. However, some fractions have not recorded position shift data and some patients do not have position shift data. The shift data for each patient will be grouped and calculated based on the axes of each axis. The result of verification of deviation of each axis will be the average ($m_{individual}$) and standard deviation ($\sigma_{individual}$) which can be processed further to obtain random and systematic setup errors.

The data collected is in the form of $\sigma_{individual}$ and $m_{individual}$ in each patient and axis. Each data will be grouped on the same axis (Supplementary Table 1 and 2). The $\sigma_{individual}$ and $m_{individual}$ data for each axis will be calculated to get σ_{setup} and Σ_{setup}.

The results in the HCC case for σ_{set-up} on each axis are 0.18 for LL, 0.39 for CC, and 0.57 cm for AP; the $\sigma_{set-up\ (Total)}$ is 0,71 cm. The results of Σ_{set-up} on each axis are 0.09 for LL, 0.20 for CC, and 0.23 cm for AP; the results of $\Sigma_{set-up\ (Total)}$ is 0.31 cm.

The random setup error on each axis in cervix tumour, are $\sigma_{set-up\ LL} = 0.32$ cm, $\sigma_{setup\ CC} = 0.32$ cm and $\sigma_{set-up\ AP} = 0.45$ cm. For systematic setup errors on each axis are $\Sigma_{set-up\ LL} = 0.22$ cm, $\Sigma_{set-up\ KK} = 0.07$ cm and $\Sigma_{set-up\ AP} = 0.45$ cm. I In the cervix tumour case, the final result sought for random and systematic setup errors is only up to the errors on each axis due to differences in conditions and anatomy; therefore, modifications are needed to apply the DTV concept.

Organ motion factors are required to obtain a random error from the ITV margin for each tumour site. For the HCC case using 1.39 cm for the organ motion and for cervix tumour, the ITV margin on the AP axis is 1.2 cm. Then the margin (M) for HCC is 1.8 cm and for the cervix region the margins for each axis are M_{LL} = 1.4 cm, , M_{CC} = 1 cm dan M_{AP} = 2 cm.The margin is then processed to get DTV. In the case of HCC, the volume of the DTV obtained ranged from 60.8–913.6 cc. In the case of the cervix tumour, the DTV volume in three patients were 2.4, 9.4, and 22.9 cc.

Tables 2 and 3 show the dose distribution in the two tumour cases by comparing the DTV plan with the clinical plan. There are several empty columns in the table indicating that in the clinical plan there is no action was taken to optimise or limit the OARs. In the HCC case, the dose-escalation in D_{max} at DTV target reached 187.3%. For the PTV-crop volume, the average D_{mean} increased to 105.36% ± 2.66%. For cervix tumour cases, the highest

dose on DTV reached 138.49%, and the average D_{max} at DTV target increased to 116.80% ± 13.19 For the PTV-crop volume, the average D_mean increased to 101.89% ± 5.58%. A larger dose delivered at the DTV will be associated with an increase in OAR. The dose increase of OAR-HCC was 106.93% ± 5.57% and OAR-cervix was 101.18% ± 1.87%. The dose-escalation in the DTV volume is a priority, and in the PTV-crop volume and OAR, there is no sign of dose-escalation.

Table 1. Margin values for HCC and cervical tumour regions calculated from random error and systematic error

Axis	Random error / σ (cm)			Total systematic error / Σ (cm)	Margin (cm)
	σ_{set-up}	$\sigma_{organ\ motion}$	σ_{Total}		
Hepatocellular Carcinoma (HCC)					
Total	0.71	1.39	1.56	0.31	1.88
Cervix					
LL	0.32		1.24	0.22	1.42
KK	0.32	1.20	1.24	0.07	1.04
AP	0.45		1.28	0.45	2.02

Table 2. Comparison between clinical planning and modified planning using the DTV concept in HCC case

No.	Parameter	Percentage (%) of dose between clinical plans and DTV plans in patient number-							Average (%)
		1	2	3	4	5	6	7	
1	D_{max} PTV	104.54	187.30	114.06	114.89	106.90	137.50	107.90	124.73 ± 29.71
2	D_{mean} PTV	107.66	109.63	111.71	104.07	97.12	110.22	102.08	106.07 ± 5.23
3	D_{max} PTV-crop	104.97	122.42	106.40	103.28	95,58	137.77	103.05	110.50 ± 14.51
4	D_{mean} PTV-crop	106.81	105.05	105.33	103.26	94,75	109.61	102.09	103.84 ± 4.69
5	D_{max} DTV	104.54	187.30	115.42	114.93	107.14	133.50	112.04	124.98 ± 29.02
6	D_{mean} DTV	109.75	138.10	119.67	106.32	115.86	113.49	102.31	115.07 ± 11.71
7	Healthy liver (700 cc *spared*)	97.86	101.96	92.51	102.54	100.00	125.88	101.20	103.14 ± 10.59
8	Healthy liver (D_{mean})	103.44	124.50	109.99	96.09	109.22	70.23	108.60	103.15 ± 16.85
9	Right kidney	92.97	94.91	103.28	106.13	92.40	92.48	98.66	97.26 ± 5.59
10	Left kidney	115.14	113.89	102.30	180.33	98.32	116.96	102.39	118.48 ± 28.25
11	*Spinal cord* (D_{max})	121.66	94.71	101.35	99.11	-	-	98.42	103.05 ± 10.67
12	*Spinal cord* (PRV D_{max})	123.26	98.06	99.55	98.87	97.40	150.91	103.21	110.18 ± 20.12
13	Duodenum	94.82	-	105.15	104.90	99.94	111.92	100.98	102.95 ± 5.80
14	Small intestine	107.48	120.59	99.71	-	102.55	108.13	101.52	106.66 ± 7.60
15	Stomach	93.53	157.98	-	-	95.72	115.48	93.65	111.27 ± 27.69
16	Esophagus	104.50	169.36	103.06	104.74	125.08	82.55	75.32	109.23 ± 31.12
17	Colon	107.55	118.02	105.22	140.93	116.15	110.88	100.04	114.11 ± 13.35
18	Ribs	103.09	107.42	102.84	108.25	-	124.61	113.52	109.96 ± 8.18
19	Heart	101.69	104.01	100.85	102.46	105.18	117.86	87.66	102.82 ± 8.83
20	Skin	101.69	110.88	100.30	113.49	-	86.67	115.54	104.76 ± 10.83

Table 3. Comparison between clinical planning and modified planning using the DTV concept in cervix tumour case

No.	Parameter	Percentage (%) of dose between clinical plans and DTV plans in patient number-			Average (%)
		1	2	3	
1	D_{max} PTV	138.03	112.32	118.71	123.02 ± 13.38
2	D_{mean} PTV	103.95	100.90	103.86	102.90 ± 1.73
3	D_{max} PTV-crop	116.71	105.59	111.73	111.35 ± 5.57
4	D_{mean} PTV-crop	101.37	100.55	103.74	101.89 ± 1.65
5	D_{max} DTV	138.49	112.77	120.56	123.94 ± 13.19
6	D_{mean} DTV	131.93	106.93	111.54	116.80 ± 13.30
7	Bladder (total dosis)	105.48	100.05	94.04	99.86 ± 5.72
8	Bladder (1 cc < 26 Gy)	106.87	100.09	97.14	101.37 ± 4.99
9	Bladder (2 cc < 24.5 Gy)	106.76	100.10	98.23	101.70 ± 4.48
10	Rectum (total dosis)	107.10	100.27	100.12	102.50 ± 3.99
11	Rectum (1 cc < 24.5 Gy)	106.69	100.24	101.05	102.66 ± 3.51
12	Rectum (2 cc < 22.5 Gy)	106.36	100.19	101.21	102.59 ± 3.31

Discussion

Verify Treatment Setup

Margin determination in DTV cannot be separated from the uncertainty factor. Random errors were obtained from the patient setup factor and organ movement factor, and those that affected the systematic error were the device setup factor and delineation error. In this study, the delineation factor was considered to be zero. The delineation was not included because it was belived that there were no errors in the description or delineation by a specialist.

Random and Systematic Setup Error

Geometric uncertainty was determined based on patient data from OBI verification. The shift was determined based on the shift of the marker monitored with OBI and then compared with the initial position at the time of CT [17]. These results will be stored in the patient's treatment data and used as a source in this study to determine the margin.

Patient setup errors are partly caused by variations in the patient's daily positioning on the treatment table and cannot be avoided [1]. Several other factors influence the preparation, planning, verification, and errors that come from the machine. In clinical conditions, the laser's position on the CT simulator must be confirmed to be the same as when the laser is on the treatment site. This will also depend on the accuracy in the verification process to reduce the error rate in the radiotherapy treatment process **[**13].

Margin

The margin for determining the DTV volume is obtained by calculating the uncertainty based on the random or systematic error which will then be used to reduce the CTV volume. From the three axes, it will then be calculated using the equation $\sqrt{LL^2 + CC^2 + AP^2}$ to derive the same value for each axis [12]. However, this concept must be modified for cervix tumour cases due to differences in anatomy and target volume.

The two tumour cases in this study exhibited differences in the size of the target volume. In the case of HCC, the size of the target volume was larger and the cervix tended to be smaller. To determine the margin, the researcher uses two different concepts. For HCC case, the margins are the same on each axis, while for the cervix tumour, the margins are different depending on the results obtained on each axis or $LL \neq CC \neq AP$. For large volumes, the margins observed by Watkins et al. [12] are more applicable. However, if the same calculation is used for the cervix, the margin will tend to be larger and cause the DTV area to be tiny; even the DTV cannot be defined. The same margin for each axis will result in a higher value than the non-uniform margin for each axis.

In addition to the reasons above, there are other factors, namely the movement of organs. Both cases of HCC and cervix tumour exhibited intra-fractional and inter-fractional movements. The movement of diaphragm and uterus tends to cause the margin to be quite different on each side. In the case of the cervix tumour, the margin tends to be more significant if the axis is related to the bladder, such as a shift in the AP axis. In contrast, the value will be smaller if the axis is not directly related to the organ. In the HCC case with a large target volume, the problems that occur in cervix tumour cases tend not to be a problem.

Defining the Definite Target Volume

DTV volume is affected by the margin, and the PRV of the tumour region studied. The PRV volume obtained did not reach the DTV in either tumour site even though an OAR was close to the tumour target. This is because the margins are relatively large due to organ movement that frequently occurs around the tumour site.

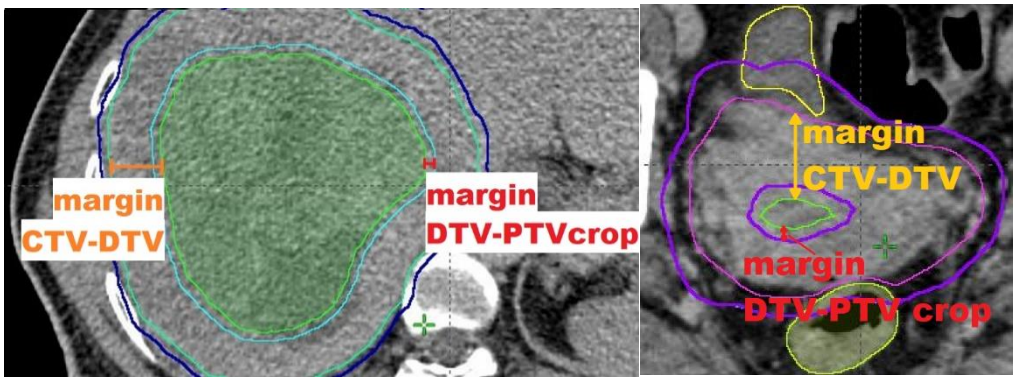

Figure 2. CTV-PTV margin and DTV-PTVcrop margin in hepatocellular carcinoma (left) and cervix tumour (right) cases. On the left figure, the light green color represents DTV and light blue represents PTVcrop with the outline shown in dark blue. On the right figure, the green line in the middle of the volume represents DTV. Light purple represents CTV and dark purple represents PTV. While PTVcrop is the volume of PTV minus DTV + margin.

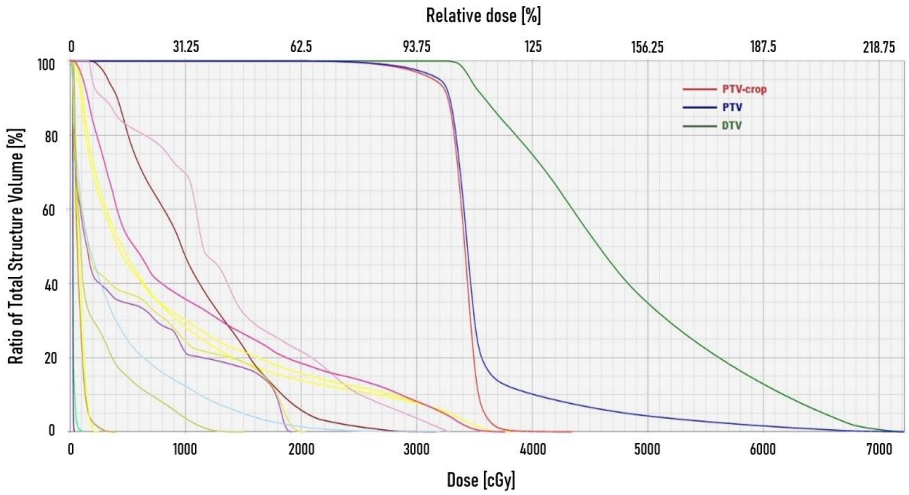

Figure 3. Dose volume histogram from planning results using the DTV concept

The primary target for optimisation in clinical planning is PTV. However, for planning using the DTV concept, PTV is divided into two; the DTV and PTV-crop. The PTV-crop was applied as PTV in clinical planning. The dose in the PTV-crop is adjusted according to the protocol used in the clinic. Meanwhile, the DTV dose will be as high as possible, the limitation being the OAR constraint. Because the dose does not allow a direct reduction in two adjacent volumes, the DTV and PTV-crop are given a margin of 0.3 cm. The DTV-to-PTV-crop margin is not too large but sufficient to realise the dose reduction in both targets. This is intended to improve the computerisation and optimisation processes.

In the HCC case, the DTV size ranged from 60.8–913.6 cc with the details described in the Results chapter. A broad range is unavoidable, and the volume for each case and each patient will always differ. In the HCC, the average ratio of DTV to CTV volume was 24.9% ± 10.3%. Meanwhile, in the cervix tumour case, the DTV volume ranged from 2.4–22.9 cc, with the average ratio of DTV to CTV being 5.6% ± 5.2%. Although only a few samples were used in the cervix case, the size of the DTV was small. This is partly due to the anatomical shape and OAR around the cervix, which causes considerable uncertainty. Uncertainty will increase the margin size and reduce the DTV.

Results of DTV Planning and Comparison to Clinical Planning

DTV planning and clinical panning will be compared with their dose differences. Comparative data can be seen in Tables 2 and 3 for both tumour cases. The target area has different concepts and volume delineation, while the OAR does not change when modified into a DTV plan. Evaluation of DTV is the essential focus of this study by examining the dose-escalation. While PTV-crop will be compared with PTV in clinical planning, although it has a different volume.

Table 2 shows the dose distribution of HCC cases with the differences shown in per cent. Using the DTV concept will affect the average dose increase in D_{max} and D_{mean} on the target and OAR. The dose-escalation in PTV-crop was 105.36% ± 2.66% due to DTV optimisation, although PTV-crop optimisation was applied as well as PTV in clinical planning. The DTV target has an average D_{mean} increase to 115.07% ± 11.71% and average D_{max} increase to 124.98% ± 29.02%. At the target, the ideal condition is a significant

increase in DTV dose, but the larger dose increase can be suppressed at PTV-crop. Patient-2 is a perfect example of the application of the DTV concept. The increase in D_{mean} for PTV-crop was 105.05% and D_{mean} for DTV targets increased up to 138.10% from clinical planning. If depicted in a dose volume histogram (DVH) for DTV targets increased up to 138.10% from clinical planning. If depicted in a dose-volume histogram (DVH) graph as shown in Figure 3, the dose on PTV-crop will immediately decrease after receiving a 95% dose and the dose decrease on DTV will ramp up until it reaches a large quantity. While the other line is showing the DVH graph for OAR.

This study was also concerned about the healthy tissue around the target. The OAR dose increased with a range from 102.82% to 118.48%. Although there was a reduced dose in the right kidney, the trend was an increase in the OAR area. Even so, the dose-escalation that occurred in OARs around the target remained below the limit or within the tolerance that applies in clinical conditions.

Likewise, in HCC, the dose also increased for the target and healthy tissue area in the cervix tumour case. In PTV-crop volume, the average D_{mean} increased to 101.89% ± 1.66%. These results were not much different from the dose obtained in the PTV in the clinical plan. The optimisation applied is in accordance with what is expected, that is, no dose is significantly increased. Meanwhile, the dose increase was quite high in DTV, with the average increase in D_{mean} at DTV being 116.80% ± 13.30%; in Patient-1, the largest increase in D_{max} was 138.49%. The target area, especially DTV, had a higher dose increase, while the OAR area had a slightly smaller dose increase than the HCC case.

This study refers to the concept introduced by Watkins et al. and the results showed a dose-escalation of DTV volume as obtained in the previous study [12]. The difference is dose-escalation on DTV compared to the prescribed dose in the Watkins work, while the dose distribution of DTV concept to the clinical plan were compared in this study.

Conclusion

The margins on the DTV concept are influenced by uncertainty factors, including verification accuracy during treatment, mechanical errors, movement and changes in organ shape. The larger margins yield smaller DTV volumes. Planning with the DTV concept allows clinical use by seeing that the DTV target can achieve high doses; the PTV-crop target has a rational dose increase and is still consistent with clinical standards for SBRT. In addition, the risk organs around the target, even though the average dose was increased, was not significant and still within clinically acceptable levels.

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