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Feasibility of Megavoltage CT for High-Dose Retrospective Planning of Helical Tomotherapy and Linac Treatment Plans: Hepatocellular Carcinoma Cancer Case

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ABSTRACT

Introduction: This work aimed to investigate the use of megavoltage CT (MVCT) images for retrospective planning in high-dose and low-fractionation radiation techniques for Helical Tomotherapy and Linac.

Material and Methods: This work used pre-treatment MVCT images for retrospective planning in high-dose hypofractionation of eight hepatocellular carcinoma (HCC) patients using the stereotactic body radiation therapy (SBRT) technique. The dose per fraction was 5.5–8 Gy in 4–5 fractions. As the patients were scanned with Helical Tomotherapy (HT) MVCT before each treatment, the selected MVCT images were registered to kVCT for re-contouring, and then the images were exported to HT and Linac for planning. The kVCT scan images were also exported from HT to Linac for planning in Linac. The final plans were compared and analyzed using the following parameters: conformity index (CI), paddick conformity index (PCI), homogeneity index (HI), and organs at risk (OAR) constraints. The dose verification was performed by gamma passing rate (GPR) test using EBT3 films.

Results: CI values were found in the range 0.7–1.00 ($\overline{CI}$: 0.95 ± 0.063), PCI values were found from 0.81 to 0.96 ($\overline{PCI}$: 0.87 ± 0.04), and HI values were found from 0.02 to 0.53 ($\overline{HI}$: 0.16 ± 0.12). OAR constraints were clinically acceptable. Distance-to-agreement of 3mm and dose difference of 3% was used as GPR criteria for each plan modality.

Conclusion: These results suggest that MVCT could be used as an alternative modality for high-dose re-planning in HT and Linac as well as being used for position verification.

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Introduction

Megavoltage Computed Tomography (MVCT) scan in HT is mandatory for verification of patient position before treatment [1]. The latest research showed that the CT number from MVCT scan has no significant variation over time in the Image Value to Density Table curve (IVDT) for the low densities region [2]. This CT number reproducibility, and the stability of MVCT images are relatively constant. Therefore the study of registration between MVCT and kVCT images from CT simulators began to be used for adaptive planning of patients [3-4]. This re-planning process could be used for patient treatment evaluation (retrospective planning). Previous work on the use of MVCT for adaptive planning in prostate cases has contributed to the decreased organ at risk (OAR) dose [5]. Adaptive planning using MVCT in upper-thigh sarcoma was also able to correct under-dosage to 2%, due to the difference in CT and the treatment conditions [6]. Moreover, Branchini *et al.* found that re-planning reduced skin dose [7]. All previous works used standard fractionation (25–30 fractions) with a dose per fraction of about 2 Gy. There are no definite results regarding the effects of adaptive planning on the plan target volume (PTV) and OAR for non-standard fractionation.

Unfortunately, the previous study mainly focused on MVCT application only for standard fractionation [2–11]. There is still no report about MVCT as a plan modality in HT treatment for hypofractionation (high-dose radiation treatment) such as stereotactic body radiation therapy (SBRT) especially for liver cancer, despite hepatocellular carcinoma (HCC) being the fourth most common cancer worldwide [12]. This ablative technique has a favorable response for the improvement of local control and patient survival in HCC cases [13-14]. Moreover, the MVCT images would be beneficial to assess the PTV, especially for image-guided radiation therapy. Nevertheless, the high dose used requires accuracy and verification of the dose distribution in both the target and surrounding organs to prevent toxicity. MVCT images have not been reported yet as being used for planning modality in

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Linac using high-dose treatment. Previous work in this area is mainly concerned with the use of cone-beam computed tomography (CBCT) as the plan modality in Linac [15] or transfer kVCT plan from HT to Linac that both are for standard fractionation [16].

This work addresses the possibility of using MVCT, which conventionally used for pre-treatment position verification before treatment, in retrospective plan modalities for treatment with low fractions and high doses in HT and Linac. Moreover, this study investigates the dosimetric planning parameter of HT and Linac treatment through the use of MVCT images in SBRT techniques for HCC cases. This study conceivably complete the previous report with the usage of MVCT for low fractionation – high dose technique in both HT and Linac, and it also addresses gaps in the pre-existing exploration of MVCT usage for planning in Linac for a backup plan in the event of machine breakdown.

Materials and Methods

MVCT calibration in Tomotherapy and Linac

The cylindrical Virtual Water™ phantom (Cheese Phantom) from HT (Gammex RMI, Middelton, WI) was scanned with 3.5 MV photon to get MVCT calibration on image values measurement. The phantom consists of two semi-cylindrical halves of solid water with 18 cm thick and 30 cm diameter. A film could be placed in between. For CT number calibration, 20 plugs, including 10 solid water plugs plus 10 different tissue substitute plugs that range in density from 0 g/cm^3 to 1.82 g/cm^3 were used as seen in Figure 1. The series of MVCT images were contoured and analyzed slice by slice in the Hi-Art HT Tomoplan planning system (Accuray Inc., Madison, USA). Since the MVCT would also be used for generating plans in Linac, MVCT calibration images were exported also to Pinnacle treatment planning system v9.10 (Philips Medical Systems, The Netherlands). Regions of interest (ROIs) with a diameter of 20 mm were contoured at the center of the phantom plugs, then the mean CT numbers in the contours of the plugs were recorded. The physical densities of each phantom plug were recorded from the manufacturer specifications, and the mean CT values recorded were plotted as the IVDT curve for HT and Linac.

Figure 1. The Cheese phantom with 20 plugs of 10 different densities.

Patient selection criteria, registration and planning

Eight HCC patients of HT with SBRT who had been treated in Cipto Mangunkusumo National General Hospital between 2017 and 2019 were included in the study. Patients received hypofractionation doses of 5.5–8 Gy per fraction in 4 to 5 fractions (total dose 27.5–35 Gy). The PTV regions must be covered by MVCT scan with a 3.5 MV photon. The image registration between MVCT to kVCT images was performed using Planned Adaptive Station HT (version 5.1) with automatic registration based on bone and tissue due to limited resources in TPS software license in advance registration technique. To assure the process, the automatic registration was re-verified and re-adjusted manually by medical physics and oncologist. The contour of target and OARs were copied from kVCT to MVCT in Planned Adaptive Station HT. Since the software has no deformation adjustment, the anatomy deformations that implicates the contours deformations were evaluated and re-contoured manually by an oncologist. The Final MVCT images were transferred from the Planned Adaptive Station of HT to Planning Station to generate a new retrospective plan in HT.

Intensity-modulated radiation therapy (IMRT) HT plans were created using the Hi-Art HT planning system (Accuray Inc., Madison, USA). For all eight cases, a field width (FW) of 2.5 - 5.02 cm, a pitch of 0.18 - 0.43, jaws 1.0 - 2.1 and a modulation factor (MF) of 1.45 - 2.47 were used during optimization with dose calculation of convolution-superposition algorithm [17].

To investigate the feasibility of MVCT images for plan-making in Linac, the final MVCT images were also exported from HT to Pinnacle v9.10 (Philips Medical Systems, The Netherlands) via digital imaging and communications in medicine (DCOM) system. IMRT plans were generated for 6 MV photon energy by Synergy S model (Elekta AB, Stockholm, Sweden) with 80 leaves and 1 cm width of leaves at the isocenter. Treatment plans were created by 9 to 11 beam angles using an adaptive convolution algorithm [18–20].

The kVCT planning in HT was used as a reference plan. To make a plan parameter comparison between MVCT and kVCT, we also transferred kVCT images from HT to Linac to generate kVCT plan in Linac. After all, plans were successfully generated, the plans were evaluated in terms of PTV and OAR dose. Since the images were exported from HT to Linac, there were also differences in plan tumor volume.

This study used available MVCT only. The retrospective plans generated in this study were used only for the research purpose. This work was authorized by the ethics committee of the Faculty of Medicine, Universitas Indonesia (Research Protocol No. 19-06-0723).

Plan evaluation

HT and Linac plans were evaluated qualitatively by using dose washes in each slice of axial, sagittal and coronal views, and quantitatively by using dose-volume histograms.

Figure 2. Cheese phantom set up for DQA (left) and Film placement, inserted in the middle of the cheese phantom.

The conformity index (CI) and Paddick conformity index (PCI) were used for the conformity evaluation of the prescribed dose to cover the target volume of the plan, and homogeneity index (HI) was used for uniformity evaluation of the plan. The CI follows the International Commission on Radiation Units and Measurements (ICRU) No. 83 report by equation 1 [21].

$$CI = \frac{V_{95\%}}{V_{PTV}} \quad (1)$$

where $V_{95\%}$ is the target volume receiving of 95% of the prescription dose, and V_{PTV} was the total PTV volume of 100%. The optimal value of the CI is 1.

The PCI evaluated a robust conformity index that measures the proportion of radiated tissue outside the target volume (overdose) and the target volume covered by radiation (underdose) [22].

$$PCI = \frac{(TV_{PIV})^2}{TV \times PIV} \quad (2)$$

where TV_{PIV} is the target volume covered by the prescription isodose, TV is the target volume, and PIV is the volume of prescription isodose. The optimal value is 1 which represents no target volume receiving underdose and no target volume of overdose.

The homogeneity Index (HI) determined by near-maximum dose ($D_{2\%}$), near-minimum dose ($D_{98\%}$), and median dose ($D_{50\%}$) as seen in equation 3 [23].

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}} \quad (3)$$

where $D_{2\%}$ is the dose value at 2% target volume (PTV), $D_{98\%}$ is the dose value at 98% target volume (PTV), $D_{50\%}$ is the dose value at 50% of the target volume (PTV). HI represents the uniformity of absorbed-dose distribution. The optimal value of zero indicates the dose distribution is almost homogeneous.

For the OAR evaluation, maximum dose (D_{max}), mean dose (D_{mean}), and appropriate specific dose or volume thresholds were recorded to estimate OAR sparing with RTOG 1112 criteria [24].

Plan verification

Plan verification was performed using the delivery quality assurance station (DQA plan) in each treatment planning system (TPS), then the radiation therapy dose (RT dose) was extracted. Gafchromic EBT3 film dosimetry system was used for dose verification for both HT and Linac. Film Lot were 10091703 and 050261701 respectively. EBT3 films were calibrated in HT and Linac using a "solid water" phantom. For plan verification, a cheese phantom was employed to replace the patient tissue for dose calculation and verification in HT and Linac as seen in Figure 2. All films were scanned by Epson 10000XL scanner with a developing time of 2 × 24 hours. FilmQA Pro and DQA HT were used to evaluate the gamma passing rate (GPR) using equation 4.

$$GPR = \sqrt{\frac{\Delta r^2}{\Delta d_M{}^2} + \frac{\Delta D^2}{\Delta D_M{}^2}} \text{ with } \Delta r = |r_r - r_c|, \text{ and } \Delta D = D_c(r_c) - D_r(r_r) \quad (4)$$

where D_c (r_c) is dose evaluation at point r_c, and D_r (r_r) is the reference dose at point r_r. The tolerance dose difference (DD) is represented by ΔD_M and the tolerance distance to agreement (DTA) by Δd_M. The verification point was declared to pass the DD and DTA for GPR if less than 1, otherwise it failed [25]. DD of 3% and DTA of 3 mm were used with the GPR of 90% [26].

Results

Linearity CT Number of MVCT in Tomotherapy and Linac

The plot of CT number to physical density could be seen in Figure 3. The lines showed the same CT number response in the physical density of less than 1 g/cm^3 for kVCT and MVCT in both HT and Linac. The CT number starts to express the difference between kVCT and MVCT in the physical density region above 1 g/cm^3.

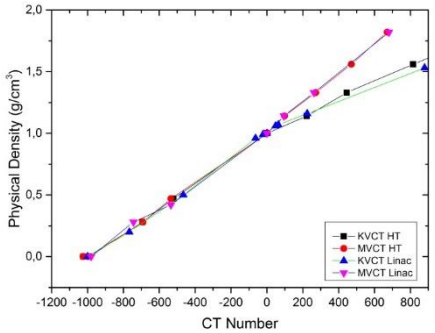

Figure 3. CT number plotted against physical density for kVCT and MVCT in HT and Linac.

The curves were analyzed using linearity and coefficient of variation (CV) tests. The linearity test is

expressed with a coefficient of determination (R) with the best result of R is 1. The CV values will be accepted if the value is less than 50%. The R-value of the MVCT and kVCT curves for HT and Linac were all 0.99. The CV values for MVCT in HT and Linac were 7% and 9.7%, and CV values for kVCT for HT and Linac were 14% and 12%, respectively. The linearity test and CV test both performed well.

Plan Evaluation

PTV differences between HT and Linac

Since the images were delivered from the HT database to Pinnacle, the PTV volume has changed due to different algorithms for the reconstruction. This PTV difference was originally evaluated by the work of Zang in head and neck cancers. In this work, PTV differences were obtained (2.06 ± 0.83)% using the equation from Zang [19]. Meanwhile, Zang discovered the difference in PTV transferred from Pinnacle to HT was lower (0.62% ± 0.59%), as the tumor size in Zang's work was smaller. However, ANOVA *p*-test value was 0.97 ($p > 0.05$). It means the differences between HT and Linac PTV volume were insignificant and the transfers were successful.

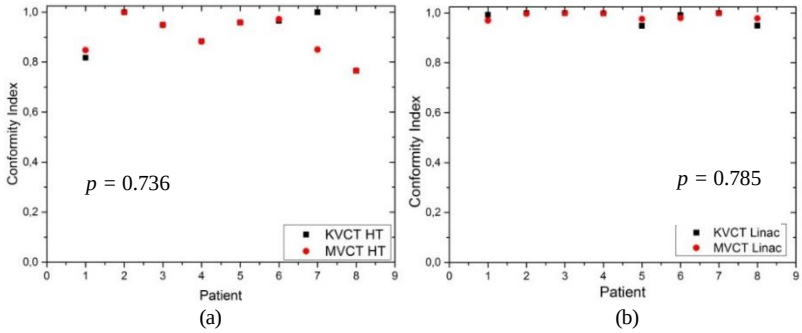

Figure 4. a) Graph of comparison between CI values for kVCT and MVCT plans in HT, and b) Graph of CI values comparison in Linac

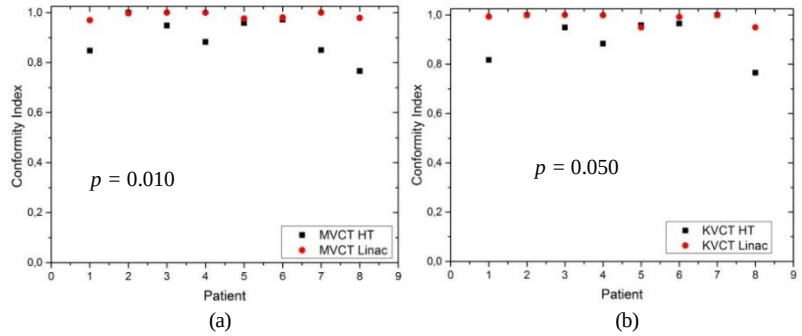

Figure 5. a) Graph of comparison between CI values for MVCT plans in HT and Linac; and b) Graph of CI values comparison for kVCT plans.

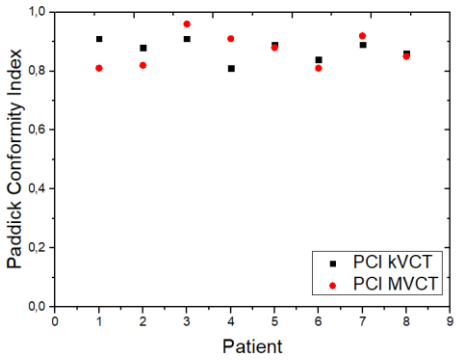

Figure 6. Graph of comparison between PCI values for kVCT and MVCT plans.

Conformity index (CI)

The CI was in the range of 0.77 to 1.00, with an average of (0.95 ± 0.06). The closer CI to 1 implies the more conformal the treatment plan. Figure 4 showed CI values for MVCT and kVCT plan in HT and Linac. The proposed MVCT plan satisfied the conformity plan criteria for HT (Figure 4a) and Linac (Figure 4b) as compared to the kVCT plan with no significant different (p > 0.05). Figure 5a showed CI of MVCT plan in HT and Linac as comparison of MVCT scan transfer between two treatment modalities. CI of kVCT in HT and Linac was displayed also in Figure 5b. All plans satisfied the CI criteria.

Homogeneity index (HI)

In general, the HI values varied in the range 0.03 to 0.28, with an average of (0.12 ± 0.02). The average HI of Linac was 0.10 ± 0.04 while the average HI of HT was 0.15 ± 0.08. Figure 7a-7b showed the HI as resulted from re-planning with MVCT scan compared to the initial kVCT scan plan. The re-planning in both HT and Linac resulted in similar HI values with no significant difference. The plans in Linac for the MVCT plan (Figure 8a) and kVCT plan (Figure 8b) were also successful as demonstrated from HI values that are close to zero. It indicates an almost uniform dose within the PTV (ICRU 83).

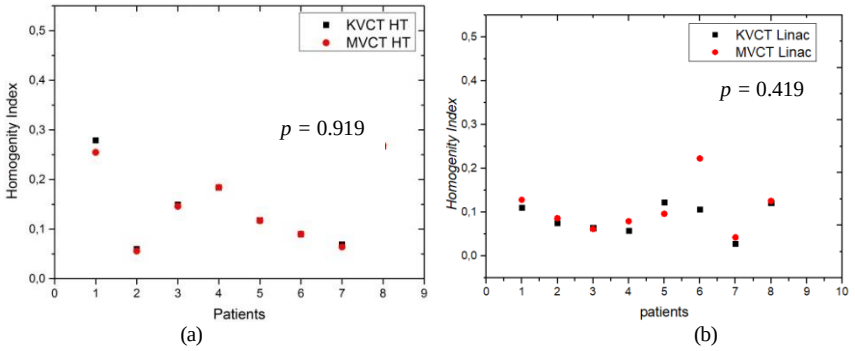

Figure 7. Graph of comparison between HI values for kVCT and MVCT in HT(a), and in Linac (b)

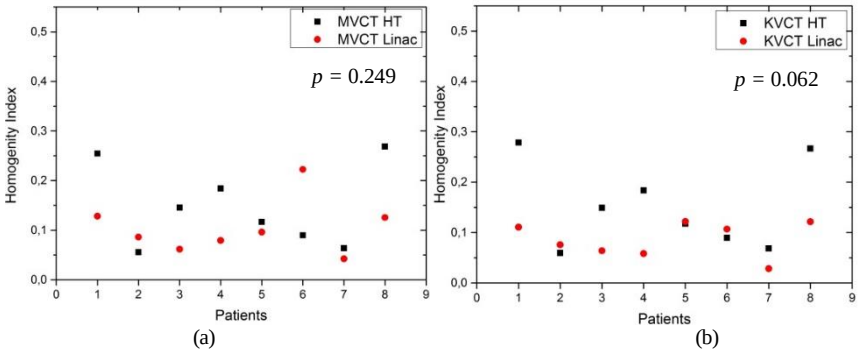

Figure 8. Graph of HI for MVCT plan in HT (a), Graph of HI for kVCT in Linac (b).

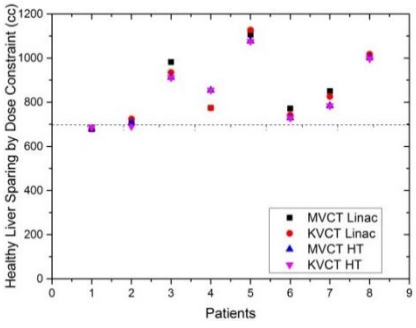

Figure 9. Healthy liver volume spared by dose constraint from RTOG criteria for certain fractions.

Table 1. *P* values of OAR dose different in term of different image modality for planning and different machine to generate the plans.

	MVCT (HT vs Linac)	kVCT (HT vs Linac)	HT (MVCT vs kVCT)	Linac (MVCT vs kVCT)
p values	0.886	0.915	0.941	0.981

Table 2. The OAR Different Dose by retrospective planning and DD by different machines.

OAR	Retrospective dose* in Linac (Gy)	Retrospective dose* in HT (Gy)	Difference dose** for kVCT (Gy)	Difference dose** for MVCT (Gy)
Kidneys	-0.51 (p = 0.79)	0.28 (p = 0.89)	0.97 (p = 0.59)	0.18 (p = 0.93)
Spinal cord	-0.45 (p = 0.89)	-0.03 (p = 0.99)	-0.44 (p = 0.71)	-0.85 (p = 0.61)
Duodenum	0.21 (p = 0.97)	-0.15 (p = 0.98)	-1.58 (p = 0.78)	-1.22 (p = 0.82)
Stomach	0.4 (p = 0.98)	-0.5 (p = 0.93)	-2.0 (p = 0.79)	-1.1 (p = 0.86)
Heart	0.2 (p = 0.98)	0.05 (p = 0.99)	0.47 (p = 0.94)	0.62 (p = 0.92)

* Retrospective dose obtained with ($kVCT_{dose} - MVCT_{dose}$): positive results mean kVCT dose was higher than MVCT, retrospective plan has benefit in reducing OAR dose (kVCT dose much higher than MVCT)
**Difference dose obtained with ($HT_{dose} - Linac_{dose}$): positive results mean OAR Linac is lower than for HT dose.

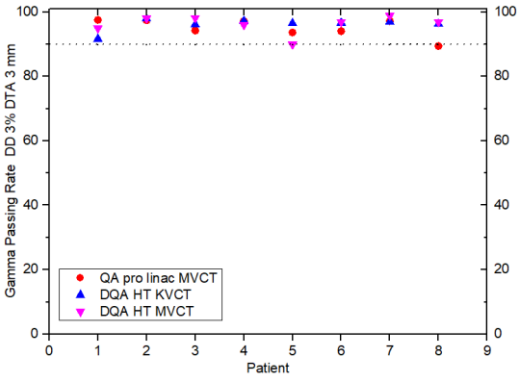

Figure 10. Patient GPR for each plan modality using various software.

Toxicity and OAR evaluation

Radiation Therapy Oncology Group 1112 (RTOG) has stated that for HCC SBRT the liver volume must be over 700 cc for certain dose limits that are proportional to total fraction [24]. For four and five fractions, the spared liver volume must be listed as dose constraints of 16.5 Gy and 17.75 Gy respectively. Spared liver of below 700 cc may lead to liver toxicity. Using RTOG criteria, the comparison between liver volume for certain dose limits of MVCT and kVCT was evaluated to investigate the effect of radiation on OAR's as presented in Figure 9. There were no significant difference in term of the OAR dose caused by a re-planning process using MVCT or transferring patient from HT to Linac, as all $p > 0.05$ (presented in Table 1). Retrospective planning in Linac showed decreasing in liver volume by 7.75 cc on average. Conversely, retrospective planning in HT increased liver volume by 4.32 cc. Transfer of patients from HT to Linac using kVCT as well as MVCT also increased average liver volume by 21.64 cc and 9.57 cc, respectively.

The OAR evaluation is shown in Table 2. Retrospective planning using MVCT images indicates a decrease of OAR dose for stomach, duodenum, and heart in Linac, and retrospective planning also decreased dose for kidney and heart in HT. Treatment in Linac compared to HT using kVCT and MVCT revealed a reduction in both OAR dose for heart and kidneys. However, the *p* test analysis showed that all of the OAR dose differences were statistically insignificant.

Dose verification

Gamma passing rate (GPR) was employed with 3% DD and 3 mm DTA criteria TG-148 for Tomotherapy DQA plans and ESTRO booklet no.7 [23–25]. GPR in linac was performed by FilmQA Pro (Ashland, USA), and GPR in HT was performed by DQA HT software. The GPR results are shown in Figure 10, and the GPR data is presented in Table 3.

Table 3. GPR with DD 3% and DTA 3mm for HT and Linac for various modalities.

Software	Modality	GPR
DQA HT	kVCT	96.16 ± 1.8*
	MVCT	96.23 ± 2.7
QA Pro Linac	MVCT	95.07 ± 2.6

*GPR of kVCT plan in DQA HT was actual clinical plan

Discussion

As MVCT images were proposed to be used for planning, the MVCT needs to fulfill these criteria: The MVCT images values have to produce the linear CT number curve in correspond to the various density, and plan evaluation of MVCT images was acceptable.

The MVCT curve linearity in HT and Linac was proven by the graph as presented in Figure 3. The photon attenuation in matter or tissue at kilovoltage and megavoltage energies was dominated by the photo-electric effect and Compton scattering. However, the photo-electric effect contributes increasingly to high atomic number of materials, so the CT numbers will increase with both electron density and an atomic number of materials in kVCT. In the megavoltage energy range, Compton interactions are dominant even at the high atomic number and photo-electric effect contribution becomes negligible. Therefore, the MVCT

number to physical density calibration is expected to reflect a linear relationship and reduce artifact [29]. In Figure 4, the CT number curves for kVCT and MVCT show a linear relationship to the physical density and they have nearly the same curves for low atomic numbers (physical density under 1 g/cm^3), as expected. As the CT number remains the same for lower physical density and is not affected by the energy, for higher physical density the curves show a different CT number response for different energy CT. The MVCT produces lower contrast (manifested in lower CT number) compared to the kVCT for the same physical density as the photo-electric interaction is absent. The lower CT number in higher physical density gives the benefit in terms of lower image distortion and artifact presence. This result support the previous studies [2,28-29].

All plans delivered conformal PTV coverage in general. The CI of plans in the same treatment modality showed no significant difference (p>0.05) between kVCT and MVCT. The different radiotherapy treatment modalities could affect the different CI values as shown by Figure 5a and Figure 5b. This difference CI showed significant in MVCT plan only. The average CI for HT was 0.90 ± 0.08 and the average CI for Linac was 0.98 ± 0.03. This work supports the previous results from Zang *et al* (CI for HT was 1.42 ± 0.21 and CI for Linac was 1.23 ± 0.11) that in average CI Linac perform slightly closer CI value to 1, but we found there is no significant difference in Linac plans (p>0.05) [19]. The PCI for the kVCT plan and MVCT plans showed close value from each other with no significant difference. The prescription isodose coverage in this work (0.87 ± 0.04) was higher than the previous work from the same case HCC by Zhao *et all.* (PCI = 0.81 ± 0.05) [17].

In general, the average HI value of Linac was 0.14, and average HI value for HT was 0.17. Both HI were clinically acceptable. The results of this study are in line with the previous study. Xu *et al.* compared HI for Linac and HI for HT used for kVCT planning in the case of lung cancer. The results of Xu's study were 0.10 for HI of Linac and 0.14 for HI of HT [31]. Another comparative HI value was tolerance range (TR), which is an indicator of homogeneity in PTV drawn from the study by Zang with HI for Linac was 0.19 and HI for HT was 0.13 [19].

The CI, PCI and HI results from this work showed that MVCT was possible to be used for planning modality purposes in hypofractionation treatment with a high dose for HCC SBRT case in HT and also for transfer patient to Linac. The different conformity and homogeneity index of the MVCT re-planning process in HT and Linac was affected by each machine's characteristics and the operating skill of the planners. In Linac, both criteria had a strong correlation with the amount of the fields, algorithm, and iteration. For the simple case, better HI and CI could be achieved by adding the fields of beam [16]. The amount of 9 and 11 fields in Linac was sufficient to get the close HI and CI results as in HT for the SBRT HCC case. As the CI and HI Linac in this work showed slightly better performance compared to HT, it was resulted from different OAR optimization. In the more complicated case, HT plans were found more superior [17,31].

The transfer issue about backup plans in Linac to continue patient treatment, previously performed by Yuan with FallBack planning, a novel TPS from RayStation that automatically converts plan from HT to a multifield IMRT or VMAT Linac plan [16]. Yuan studied in kVCT patient transfer using FallBack planning, but there was no report for MVCT plan from HT to Linac. This work proved MVCT patient transfer between HT and Linac was possible. The effects of retrospective planning using MVCT on OAR doses in this work were quite different from the previous studies that stated retrospective or adaptive planning reduced OAR dose [5,7,15]. While re-planning decreasing heart dose in Linac and HT, the dose decline did not appear in other organs. Nevertheless, the plans in Linac show an OAR dose increase. In HT, kidneys benefited from retrospective planning by reducing 0.28 Gy compared to the initial plan by kVCT, while in Linac this worsened in retrospective planning with a 0.51 Gy difference. The other results show that retrospective planning will increase the spinal-cord dose by 0.45 Gy in Linac and 0.03 Gy in HT. In Linac, retrospective planning could decrease the duodenum and stomach dose, but in contrast, could increase the dose in HT. As shown by Table 2 columns 3 and 4, the treatment in HT seems to give better results in OAR dose of the spinal cord, duodenum, and stomach. These results confirmed with the study reported by Koca *et al.* [18]. The liver's healthy improvement or OAR dose reduction by the retrospective plan was insignificant due to the short fractions and liver cancer characteristics. No statistically significance was observed for all OAR's dose parameters. All treatment plans were found to have similar efficiency and evaluated as acceptable for patient treatment. OAR analysis from this work and the previous works showed that OAR dose different not consistently significant [19,31-32].

The average GPR of MVCT by DQA HT and FilmQA Pro Linac was (96.23 ± 2.7) and (95.07 ± 2.6), respectively. The gamma passing rate was local with no minimum dose threshold. This GPR average by the DQA HT for both plans was close to the results by Chung *et al.* (99.6) and Cho *et al.* (95.3) [33-34]. The average Linac GPR plan by FilmQA Pro was lower compared to HT GPR by DQA HT. These variations in GPR are caused by the different mathematical techniques used to refine/speed up the gamma index calculation or by graphical processing units from computational techniques from the software and computers used [25]. In FilmQA Pro, the resolution of Linac RT dose has been manually adjusted to 72.57 dpi as closest to the film resolution 72 dpi, whereas in DQA HT it was automatic. The high dose of treatment and the wide irregular form of the target in this study produced dose differences that occurred in the steep dose gradient region, affecting the gamma index pass rate [35].

In general, for both Linac and HT, planning using MVCT modalities in HCC cases could produce plan evaluation outcomes which have no significant difference from plan evaluations using kVCT. Retrospective planning using MVCT scans in HT and Linac for HCC cases with SBRT technique was possible while maintaining Linac dosimetry performance for criteria CI, HI, and OAR dose. These findings address gaps in the pre-existing exploration of MVCT usage for HT that was previously used only for conventional plan techniques and exploration in plan transfer from HT to Linac.

Conclusion

A dosimetric comparative evaluation was performed for 8 HCC SBRT patients. All planning satisfied the PTV prescription requirements and OAR dose constraints. It could be concluded that MVCT could be a feasible modality for planning in HT and Linac for HCC. Additionally, the results of our work have proved that MVCT could be used for high-dose plan modality. However, re-planning in SBRT did not meet the significant improvement in conformity index, Paddick conformity index, homogeneity index, and OAR constraint as expected before.

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