Dosimetry verification on VMAT and IMRT radiotherapy techniques: In the case of prostate cancer

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Abstract. Radiotherapy treatment depends on the accuracy of the dose delivery to patients, the purpose of the study is to verify the dose in IMRT and VMAT technique in prostate cancer cases correspond to TPS dose using phantom base on ICRU No.50. The dose verification of the target and OAR was performed by placing the TLD Rod LiF100 and EBT2 Gafchromic film at slab hole of pelvic part of the Alderson RANDO phantom for prostate cancer simulation. The Exposed TLDs was evaluated using the TLD Reader Harshaw while EBT2 film was scanned using Epson scanner. The point dose measurements were compared between planned dose and measured dose at target volume and OAR. The result is the dose difference at target volume, bladder and rectum for IMRT and VMAT are less than 5%. On the other hand, the dose difference at the Femoral head is more than 5% for both techniques because the location of OAR already in low gradient dose. Furthermore, the difference dose of the target volume for IMRT technique tends to be smaller than VMAT either for TLD and EBT2 film detectors. From the measurement showed that the delivered dose on the phantom simulation match with ICRU No.50 criteria.

1. Introduction
Prostate cancer is a type of cancer that commonly occurs in the prostate gland, and usually affects men over the age of 50 years and above. In Indonesia, the number of patients with prostate cancer is in the third ranks after cervical and breast cancer whose number is estimated around 25,012 people [1]. Common treatment methods and efficiently used for the treatment of prostate cancer is radiotherapy to kill malignant cancer cells or reduce their growth [2].

The success of radiotherapy treatment planning systems depends on the accuracy of the dose delivery to patients, which includes determining the volume of cancer, determination of the dose to be delivered and how the treatment is done. ICRU No. 50 and 62 recommended that the dose uniformity in the target organ must be within uncertainties in the range of + 7% and -5% [3].

Several studies on dosimetry verification of prostate cancer explained that VMAT delivered more efficient technique with the maximum dose of the target cancer and minimal on healthy tissue could be done by (rectum, bladder and femoral head) [4, 5] and also faster with less Monitor Units compare to the IMRT technique [6, 7]. Klein et al. conducted a verification dose in the case of prostate cancer on IMRT and VMAT techniques using deformable anthropomorphic phantom and plastic scintillation detector explained that the differences of the measured dose of target volume compared to TPS at about 1.2% and 10.1% for IMRT and VMAT, respectively [8]. In addition Blais et al., did the
experiment using Rando anthropomorphic phantom and detector TLD and obtained the difference measure dose of the target volume and planned dose around of 1.1% for IMRT techniques [9].

The purpose of the study is to verify the dose in IMRT and VMAT radiotherapy technique in prostate cancer cases correspond to planned dose (TPS) using phantom base on ICRU No.50.

2. Materials and methods
This work was performed at using Linear accelerator RapidArc Varian Clinac with 120 MLC which produce two X-ray photon beams 6 MV and 15 MV. In this study, we only used x-ray photon beams 6 MV during the experiment. The planning was done using Eclipse Treatment Planning System version 11.0 that capable of doing the planning of IMRT and VMAT techniques.

Prior to dosimetry In order to provide the additional data and evaluate the implementation of IMRT and VMAT, we proposed to do the verification, the calibration of TLD for x-ray 6 MV was done at water phantom to obtain a conversion factor using condition of field size 10 cm × 10 cm, 10 cm depth and 100 cm SAD. Prior to the experiment, the annealing process of TLD was carried out for one hour at the temperature of 400°C and 2 hours at the temperature of 100°C. The exposed TLDs with the single dose of 200 cGy were then compared to the readings with the ionization chamber detector under the same conditions.

Additionally, calibration of the Gafchromic EBT2 film was done to determine the pixel value conversion factor to dose. The Films were sandwiched between layers of solid water phantom at 10 cm depth and exposed using x-rays photon 6 MV with 100 cm SAD and field size of 10 × 10 cm². The films were irradiated with varied dose as indicated MU variation in the range of 20, 40, 80, 120, 160, 200, 240, 280, 320, 360 and 400. The films were then scanned using Epson scanners V700 with red channel and resolution of 72 dpi. After the image was saved in. TIFF format, the calibration curve was generated as a function between pixel value and dose.

The patient was simulated by Rando phantom using Philips CT-Scan to get an image and transferred to radiotherapy planning system for IMRT and VMAT technique optimization. In TPS planning, PTV was simulated in the prostate, while OAR of this case are bladder, rectum, right femoral head and left femoral head. The total planned doses for target volume was about 80 Gy and given in 40 fractionation (2 Gy).

For dose verification, the point measurements were done using TLDs and EBT2 Gafchromic films. Both detectors were inserted to Rando phantom at the simulated target volume and organ at risk. We decided to put 3 points of the target and 4 points at OAR for Bladder, Rectum, right Femoral Head and left Femoral Head as illustrated in figure 1.

The orientation of TLDs at Rando phantom were in coronal position while the EBT2 Gafchromic film will be varied on coronal and axial orientations. The films were cut into 1 × 1 cm² for axial orientation, and the size of film of coronal orientation was 1 × 0.5 cm².

After irradiation during IMRT and VMAT techniques, TLDs were read using TLD reader Harsaw and the films were scanned using Epson Perfection V700 using transmission mode, the red channel, and resolution of 72 dpi.

Figure 1. The measurement points in Rando phantom for prostate cancer simulation.
In order to evaluate and analyze the data, we used the formula as indicated in AAPM Task Group 119. The dose difference (Δ in %) was calculated using the Equation (1) as follows:

$$\text{Dose Difference (\%) = \frac{D_{\text{measured}} - D_{\text{plan}}}{D_{\text{plan}}} \times 100 \%} \quad (1)$$

where \(D_{\text{measured}}\) is measured dose in both detectors, \(D_{\text{plan}}\) is the planned dose at TPS. Afterward, the results of calculation were evaluated in accordance with ICRU recommendation and criteria.

3. Results and discussion

The point dose measurement of the target volume and organ at risk for IMRT technique are illustrated in figure 2. From the figures 3, the dose difference between point dose at the target between measurement and planning in the range of -0.46 to 6.62%, -2.04 to 6.49%, -1.46 to 6.26% for right peripheral, isocenter and left peripheral, respectively. In addition, the dose difference at OAR in the range of -0.60 to 5.57%, 2.75 to 3.87%, -13.26 to 11.18%, -21.40 to 8.01% for bladder, rectum, right femoral head and left femoral head, respectively.

On the other hand, the point dose measurement of target and OAR for VMAT can be seen in figure 4. The figure 5 shows that the dose difference of target in the range of -0.58 to 6.68%, -2.03 to 6.46%, -3.31 to 6.13% for right peripheral, isocenter and left peripheral, respectively, while it was found at OAR in the range of -1.72 to 5.12%, -1.68 to 5.04%, -14.89 to 5.72%, -8.26 to 12.18% for bladder, rectum, right femoral head and left femoral head, respectively.

If we compare the results of this work with the previous study, we found that the pattern of dose difference of IMRT technique tends lower than VMAT technique in accordance with Blais works. Blais et al. showed the dose discrepancy for IMRT around of 1.1%. Additionally, Klein et. al showed that the difference dose around of 1.2% and 10.1% for IMRT and VMAT techniques, respectively.
From table 1, the dose at the target in VMAT technique has relative error tend to greater than dose deviation of IMRT technique. The hypothesis of this phenomenon is the difference fluence of VMAT happens during the treatment that means the detectors received the difference fluence during the measurement compared to IMRT technique. It means the point of the detector received difference fluence during the measurement, so it can be a source of higher uncertainties of the measurement during VMAT techniques. The use of gafchromic in this case has shown larger deviations than TLD. It can be happen due to the calibration process and angular dependent.

Table 1. Relative errors dose on target volume prostate cancer in IMRT and VMAT techniques.

| Research                     | Detector                    | IMRT  | VMAT  |
|------------------------------|-----------------------------|-------|-------|
| This Work                    | TLD                         | -1.69%| -1.99%|
|                              | EBT2 Coronal                | 4.53% | 4.84% |
|                              | EBT2 Axial                  | 6.03% | 6.44% |
| David Klein [8]              | Plastic Scintillation Detector | 1.20% | 10.10%|
| Adam Richard Blais [9]       | TLD                         | 1.10% |       |

The doses of both the bladder and rectum in IMRT technique are higher than VMAT technique for TLD, film and TPS. While, the dose of the right femoral head with IMRT is lower than VMAT using TLD and films. On the other hand, the dose of right and left femoral head with IMRT technology is lower than VMAT technology for TLD and film measurement.

The dose difference of bladder and rectum as less than 6% for all detectors, whereas dose difference of femoral head occurred in the range of 8 to 21%, 1 to 7%, 5 to 11% for TLD, EBT2 coronal and EBT2 axial. We may conclude those rectum and bladder doses are around 6%, because it is close to the PTV. However, the dose difference of the femoral head more than 6%, because the location of femoral head occurs in low dose gradient so it makes the higher relative errors on the measured dose compared to planned dose on the TPS.

Table 2. Surface dose estimation for IMRT and VMAT techniques.

| Organ            | TLD IMRT (cGy) | TLD VMAT (cGy) | EBT2 IMRT (cGy) | EBT2 VMAT (cGy) |
|------------------|----------------|----------------|----------------|----------------|
| AP pelvis        | 18.37          | 12.50          | 14.83          | 19.18          |
| Right pelvis     | 12.40          | 17.65          | 18.17          | 20.34          |
| Left pelvis      | 8.76           | 13.06          | 21.13          | 20.42          |
| Thyroid          | 4.92           | 0.12           | 5.32           | 6.18           |
| Right eye        | 4.93           | 0.13           | 5.67           | 5.67           |
| Left eye         | 4.92           | 0.12           | 6.69           | 6.53           |

Finally, the table 2 shows the comparison of surface dose during IMRT and VMAT treatment for AP pelvis, right pelvis, left pelvis, thyroid, left and right eye. Table 2 showed that the surface dose of IMRT tend to be smaller than VMAT dose if we are using TLDs, but the dose of EBT2 film tends to be similar between IMRT and VMAT techniques.

4. Conclusion
From this study, it can be concluded that the delivered dose on the phantom simulation for the prostate cancer using IMRT and VMAT technique produced the dose difference at target volume for IMRT and VMAT are less than 5% and match with ICRU No.50 criteria.

References
[1] Kementrian Kesehatan RI 2013 *Data riset kesehatan dasar 2013* Balitbangkes
[2] Korhonen L 2009 *Methods for dose calculation and beam characterization in external photon beam radiotherapy* (Finland: Helsinki University of Technology) Dissertations p 197
[3] ICRU 1976 Determination of absorbed dose in a patient irradiate by beams of X or gamma rays in radiotherapy procedures ICRU Report 24 Bethesda Maryland

[4] Zhang P, Happersett L, Hunt M, Jackson A, Zelefsky M and Mageras G 2010 Volumetric modulated arc therapy: planning and evaluation for prostate cancer cases Int J Radiat Oncol Biol Phys 76 pp1456–62

[5] Davidson M T, Blake S J, Batchelar D L, Cheung P and Mah K 2011 Assessing the role of volumetric modulated arc therapy(VMAT) relative to IMRT and helical tomotherapy in the management of localized, locally advanced, and post-operative prostate cancer Int J Radiat Oncol Biol Phys 80 pp 1550–58

[6] Leszczynski W, Slosarek K and Szlag M 2012 Comparison of dose distribution in IMRT and RapidArc technique in prostate radiotherapy Rep Pract Oncol Radiother 17 pp 347–51

[7] Hardcastle N, Tomé W A, Foo K, Miller A, Carolan M and Metcalfe P 2011 Comparison of prostate IMRT and VMAT biologically optimized treatment plans Med Dosim 36 292–8.5

[8] Klein D, Briere T M, Kudchadker R, Archambault L, Beaulieu L, Lee A and Beddar S 2012 In-phantom dose verification of prostate IMRT and VMAT deliveries using plastic scintillation detectors Radiation Measurements 47 921-929

[9] Blais A R, Lederer E, Oliver M and Leszczynski K 2012 Static and rotational step-and-shoot IMRT treatment plans for the prostate: A risk comparison study Medical Physics 39(2)