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A STUDY ON WORKLOAD OF A MEDICAL LINEAR ACCELERATOR AT A HIGH THROUGHPUT CANCER TREATMENT CENTRE IN SRI LANKA

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ABSTRACT

Radiotherapy bunker design depends on several factors, and among them, workload is one of the important factors. Workload is calculated from the radiation dose delivered at the isocenter. Due to the introduction of new radiotherapy treatment modalities and an increasing number of new cancer patients, there is a higher possibility to increase the workload. Therefore, this study aims to assess the workload of Varian linear accelerator vault at Apeksha Hospital, Maharagama. Data were collected from 1st of August 2020 to 30th November 2020. Dose delivered at isocenter from the 3D-CRT procedures with 6 MV and 15 MV photon energy, the IMRT procedures with 6 MV photon energy and the quality assurance (QA) procedures were collected from ARIA patient management system and transferred into Excel spread sheet for data analysis. The calculated weekly workload was 2326 Gy/week with a 43% contribution from the IMRT procedures with 6 MV, 39% contribution from the 3D-CDT procedures with 6 MV, 16% contribution from the 3D-CDT procedures with 15 MV and 2% contribution from physics workload (QA procedures). The evaluated workload is higher than the NCRP recommended workload of 1000 Gy/week. This study recommends for at least a one-year survey for more accuracy on workload assessment, and also to evaluate the use factor since most of the advanced radiotherapy treatment techniques use high number of monitor units which will increase the leakage radiation.

KEYWORDS: Workload, Linear accelerator, 3-dimensional conformal radiotherapy, Intensity-modulated radiotherapy, Quality Assurance procedures

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1. INTRODUCTION

Cancer is one of the leading causes of death and a major obstacle to increasing life expectancy in every country in the world. According to the GLOBOCAN report, 19.3 million new cancer cases and about 10 million deaths have been reported worldwide in 2020 (Sung et al., 2021). In Sri Lanka, 29604 new cases and 16691 deaths have been reported in 2020 (WHO, 2023). Radiotherapy is one of the major cancer treatment options and about 50% of cancer patients receive radiotherapy during their course of treatment as an integral part of treatment (Baskar et al., 2017, Ramanathan V, 2021). With the advent of Multileaf Collimators (MLCs), there are several advanced radiotherapy modalities currently available such as 3-dimensional radiotherapy (3D-CRT), intensity modulated radiotherapy (IMRT), image guided radiotherapy (IGRT), tomotherapy, volumetric arc therapy (VMAT) stereotactic body radiation therapy (SBRT), FLASH radiotherapy and stereotactic radiosurgery (SRS) (Ramanathan, 2017). Due to the evolving nature of radiotherapy treatment modalities, the structural shielding design of conventional radiotherapy bunker should be assessed according to the new workload and use factor of the radiotherapy equipment.

Radiotherapy bunker design and shielding are the very crucial part before installing new radiotherapy equipment. The aim of shielding is to limit the radiation exposure level to staff and public. When photon and neutrons are generated, the recommended quantity for shielding design is dose equivalent (H), which is defined as the product of absorbed dose and quality factor for particular ionizing radiation (ICRU, 1993). The recommended quantity for low linear energy transfer (LET) particles is air kerma (K_a) (NCRP, 2004). In addition, the recommended quantity for a person's radiation protection is the effective dose (E) which is defined as the sum of the weighted equivalent doses to specific organs or tissue (NCRP, 1993).

Workload is one of the indications of output radiation per week for external beam radiotherapy. Typically, 50 patients are treated with a medical linear accelerator during 8 hours per day. NCRP Report 49 (NCRP, 1976) suggests the workload of 1000 Gy/week for megavoltage facilities. It can be applied for dual energy linear accelerator also. NCRP Report 51 (NCRP, 1977) recommends 500 Gy/week for higher energies and remaining workload being contributed from electron therapy or low energy x-rays. Patient workload was traditionally calculated for conventional radiotherapy treatment. The introduction of advanced radiotherapy modalities such as IMRT, VMAT and Flattening Filter Free (FFF) has made some challenges on patient workload and use factors which are completely different from the conventional treatment. Therefore, this study aims to assess the patient workload for Varian Clinic 2300CD unit at Apeksha Hospital, Maharagama, Sri Lanka.

2. MATERIALS AND METHODS

In order to design the shielding structure for a modern linear accelerator installation, dose delivered at isocenter and leakage radiation which depends on delivered monitor units (MUs) need to be considered. This study mainly focuses on assessing weekly workload to compare with NCRP recommended weekly workload. It is a retrospective study. Data were collected from 1st of August 2020 to 30th November 2020 in the Varian Unit at Apeksha Hospital, Maharagama. In this study, 3D-CRT and IMRT treatments with 6 MV photon and 15 MV photon were included. Electron treatments were excluded. All the treatment data were accumulated from ARIA patient management system. The collected data were transferred to Excel spread sheet. In addition, all relevant quality assurance procedures which were performed during this data collection period were accumulated from the chief physicist of Apeksha Hospital. The data were analyzed using Microsoft Excel.

3. RESULTS

Figure 1 shows the treatment room layout for Varian linear accelerator at Apeksha Hospital, Maharagama. A total number of procedures which were performed by using 3D-CRT treatment technique with 6 MV photon energy during 4 months of workload survey are shown in table 1. By using this treatment modality, a higher dose was delivered in September 2020 and also a maximum number of treatments were performed in September 2020. Looking at the IMRT procedures with 6 MV photon energy during this survey, a maximum number of procedures were performed in October 2020 but a higher dose was delivered at isocenter in September 2020. Considering the 3D-CRT treatment technique with 15 MV photon energy during this survey, a maximum number of procedures were performed in September 2020 and also a maximum dose was delivered at isocenter in September 2020. Figure 2 and figure 3 show the pie chart of total workload for 6 MV photon energy and 15 MV photon energy procedures.

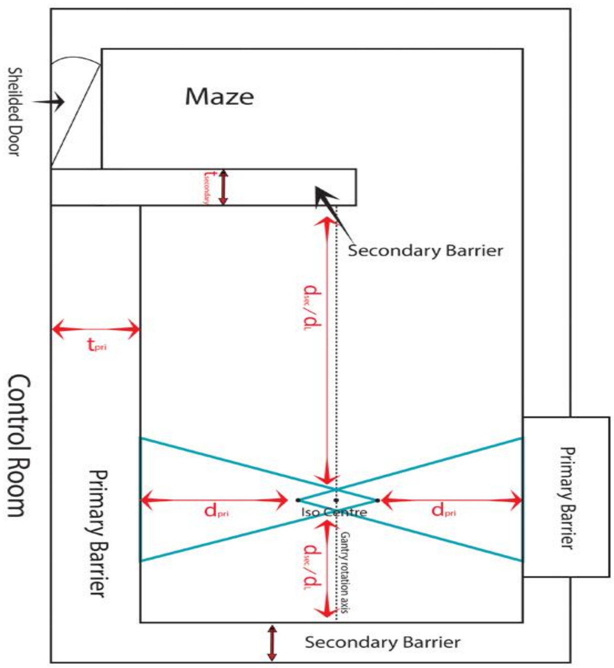

Figure 1: Treatment room layout of Varian linac vault at Apeksha Hospital.

Table 1: Total number of treatments and total dose delivered at isocenter with 6 MV 3D-CRT procedures.

Month	Total dose delivered at isocenter (cGy)	Number of treatments
August, 2020	544251.72	742
September, 2020	577595.86	842
October, 2020	164220.28	624
November, 2020	135562.91	541

Table 2: Total number of treatments and total dose delivered at isocenter with 6 MV IMRT procedures.

Month	Total dose delivered at isocenter (cGy)	Number of treatments
August, 2020	584667.02	548
September, 2020	694643.23	661
October, 2020	145698.78	706
November, 2020	98496.46	471

Table 3: Total number of treatments and total dose delivered at isocenter with 15 MV 3D-CRT procedures.

Month	**Total dose delivered at isocenter (cGy)**	**Number of treatments**
August, 2020	174388.14	492
September, 2020	270901.17	709
October, 2020	98529.34	513
November, 2020	61328.65	270

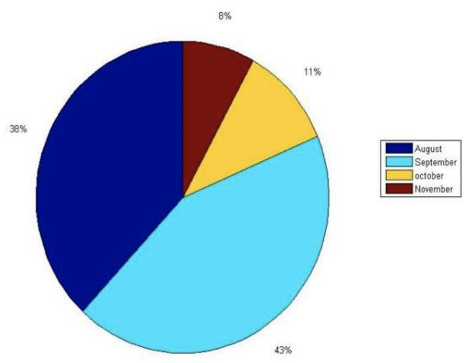

Figure 2: Total workload for 6 MV photon energy procedures for each month during the study period.

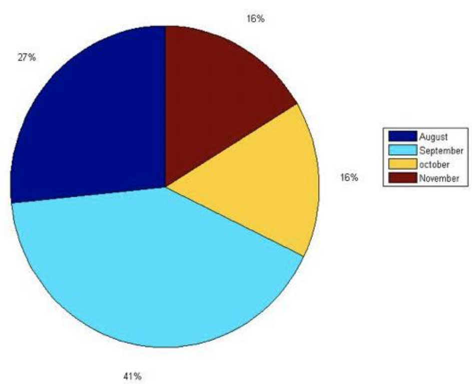

Figure 3: Total workload for 15 MV photon energy procedures for each month during the study period.

Shielding design goals, which are the practical values of a set of radiotherapy source or a single source, are evaluated at a reference point beyond a protective barrier. The shielding design goals are generally expressed as weekly values since workload for a radiotherapy source is traditionally used in a weekly format (NCRP, 2005). The calculated weekly workload for the 3D-CRT technique with 6 MV photon energy and 15 MV photon energy were 899.83 Gy/week and 384.32 Gy/week respectively. The estimated workload for IMRT treatment technique with 6 MV photon energy was 996.09. There is no workload for the IMRT treatment technique with 15 MV photon energy. Workload for the quality assurance (QA) procedures were 2000 cGy/week for monthly QA procedures, and approximately 7125 cGy/week dose was delivered at isocenter for the daily QA procedures.

Overall weekly workload for the 3D-CRT, IMRT and QA procedures (physics workload) with 6 MV photon energy was 1918.97 Gy/week and the overall workload for 15 MV procedures was 407.37 Gy/week. Finally, the weekly workload including all procedures with both photon energy of 6 MV and 15 MV was 2326.34 Gy/week (see table 4 and 5).

Table 4: Average weekly workload for 3D-CRT and IMRT treatment procedures.

3D-CRT		IMRT	
Workload for 6 MV (Gy/week)	Workload for 15 MV (Gy/week)	Workload for 6 MV (Gy/week)	Workload for 15 MV (Gy/week)
899.83	384.32	996.09	0

Table 5: Average total workload for one week.

6 MV (Gy/week)	15 MV (Gy/week)
1918.97	407.37

4. DISCUSSION

This study aimed to assess the weekly workload of Varian Clinic 2300CD linear accelerator vault at Apeksha Hospital, Maharagama. The purpose of radiation shielding was to reduce the equivalent dose from source of radiation to point outside the room (Bunker) to a sufficiently low level of radiation. The required shielding was calculated based on the weekly workload of the machine, the distance from the source/isocenter to the point being shielded, modified by the fraction of time that the beam was pointed in that direction, and the fraction of the working week that the space was occupied.

This study only focused on weekly workload measurement since the introduction of advanced radiotherapy modalities has made some challenges on patient workload. The calculated weekly workload for all treatment procedures of 3D-CRT planned with 6 MV photon energy (39% contribution), IMRT planned with 6 MV photon energy (43% contribution), 3D-CRT planned with 15 MV photon energy (16% contribution) and physics workload (QA procedures) (2% contribution) was 2326.34 Gy/week. But, NCRP Report (NCRP, 1976) suggests a weekly workload of 1000 Gy/week.

Ziad et al., 2017 did a 10-year survey of workload from 2006 to 2015 for 10 treatment vaults in USA. The dose delivered to isocenter in 2016 was (300±116) Gy/week. It was well below the NCRP recommended value. Another study was performed with 16 tomotherapy vaults in Korea. They have evaluated the weekly workload to be in the range of 600 to 14720 Gy/week. It indicates that new technology produces high workload. In the current study also IMRT treatment technique workload has a higher contribution (43%) than other treatment techniques.

In the current study, weekly workload was approximately 2326 Gy/week, which is a relatively higher weekly workload. The reasons for the higher weekly workload are the increasing number of new cancer cases that increases the number of treatment procedures per day (Ramanathan V, et al., 2022), the usage of advanced treatment modality of IMRT, and the availability of a limited number of linear accelerators (Ramanathan V, 2021). In Sri Lanka, 7 government hospitals and 2 private sector hospitals provide radiotherapy treatment facilities. Sri Lanka has only 0.93 megavoltage radiotherapy machines per one million people. It is very less comparing with International Atomic Energy (IAEA) recommendation of 4 to 8 radiotherapy centres per one million people (Ramanathan et al., 2022).

5. CONCLUSION

The calculated weekly workload was 2326 Gy/week with a 43% contribution from the IMRT procedures with 6 MV, 39% contribution from the 3D-CDT procedures with 6 MV, 16% contribution from the 3D-CDT procedures with 15 MV and 2% contribution from physics workload (QA procedures).

The evaluated weekly workload of Varian linear accelerator vault at Apeksha hospital was relatively high compared to NCRP suggested value of 1000 Gy/week. Since this study considered a survey of only 4 months, we recommend to perform at least a one-year survey for more accurate calculation of weekly workload. This study further recommends to evaluate the use factor since most of the advanced treatment techniques in radiotherapy use higher number of monitor units which will increase the leakage of radiation.

6. REFERENCES

Baska, R; Itahana K (2017). Radiation therapy and cancer control in developing countries: Can we save more lives? Int J Med Sci. 2017;14(1): pp.13-17. https://doi:10.7150/ ijms.17288.

Globocan 2020. Global Health Observatory. Geneva: World Health Organization, https://gco.iarc.fr/today/data/factsheets/populations/144-sri-lanka-fact-sheets.pdf; 2021 [accessed 24 April 2023].

ICRU (1993). International Commission on Radiation Units and Measurements. *Quantities and Units in Radiation Protection Dosimetry*, ICRU Report 51, Oxford University Press.

Kwang, H C; Jae, H J; Chul, K M; Sun, H B; Seong, K M; Eun, S K; Sam, J C; Rena, L (2018). Survey of Radiation Shielding Design Goals and Workload Based on Radiation Safety Report: Tomotherapy Vault, Korean Society of Medical Physics, pp.2508-4445.

NCRP (1976). National Council on Radiation Protection and Measurements. *Structural Shielding Design and Evaluation for Medical Use of X Rays and Gamma Rays of Energies up to 10 MeV*, NCRP Report No. 49, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

NCRP (1977). National Council on Radiation Protection and Measurements. *Radiation Protection Design Guidelines for 0.1-100 MeV Particle*

Accelerator Facilities, NCRP Report No. 51, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

NCRP (2004). National Council on Radiation Protection and Measurements. *Structural Shielding Design for Medical X-Ray Imaging Facilities*, NCRP Report No. 147, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

NCRP (2004). National Council on Radiation Protection and Measurements. *Structural Shielding Design for Medical X-Ray Imaging Facilities*, NCRP Report No. 147, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

Ramanathan V (2017). Measuring cross-section data for prompt gammas emitted during proton-nucleus collisions PhD Thesis, University of Cape Town, South Africa.

Ramanathan, V (2021). The current role of Cobalt-60 teletherapy in cancer care. *KDU J. of Multidisciplinary Studies*, 3(2), pp.80–88. DOI: http://doi.org/10.4038/kjms.v3i2.31

Ramanathan, V; Balawardane, J; Dilip Kumara, A H; Sarasanandarajah, S (2022). Current status and future prospects of radiation oncology in Sri Lanka. Phys Med. 100:pp.6-11. doi: 10.1016/j.ejmp.2022.06.001. Epub 2022 Jun 11. PMID: 35700666.

Ramanathan, V; Gunarathne, K; Sampath, D.C; and Rizwy, M.M (2022). Evaluation of Set-Up Errors and Set-Up Margin in Three-Dimensional Conformal Radiotherapy for Pelvic Tumours by Using Electronic Portal Imaging Device. *KDU J. of Multidisciplinary Studies*, 4(2), pp.77–85. DOI: http://doi.org/10.4038/kjms.v4i2.53

Saleh, ZH; Jeong, J; Quinn, B; Mechalakos, J; St Germain J; Dauer, LT (2017). Results of a 10-year survey of workload for 10 treatment vaults at a high-throughput comprehensive cancer center. J Appl Clin Med Phys. 18(3):pp.207-214. doi: 10.1002/acm2.12076. Epub 2017 Apr 19. PMID: 28422421; PMCID: PMC5689849.

Sung, H; Ferlay, J; Siegel, RL; Laversanne, M; Soerjomataram, I; Jemal, A; Bray, F. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin 2021;71: pp.209–49.