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Original Research Article

Shielding design and calculation of a treatment room for a 15-MV versa HD LINAC at BMU, Dhaka, Bangladesh

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ABSTRACT

Background: Effective shielding design is essential for ensuring radiation safety for both patients and healthcare staff in medical radiation therapy facilities, particularly with high-energy LINACs. This study investigates the shielding design and calculation for a 15-MV versa HD LINAC treatment room at Bangladesh Medical University (BMU), focusing on primary and secondary radiation barriers.
Methods: Shielding design and calculation were performed using empirical equations based on NCRP report no. 151 (2005). Maximum photon energy (15 MV) was considered for barrier design. Calculations for primary and secondary barrier thicknesses were performed using workload, use factor, and occupancy factor, with ordinary concrete (2.35 g/cm^3) as the material. Radiation levels were measured at various gantry positions (0°, 90°, and 270°) with calibrated radiation detectors.
Results: The primary barrier thicknesses were calculated as 2.75 m for east and west sides, and 2.58 m for the roof. Secondary barrier thicknesses for the north, south, and roof sides were 1.02 m, 1.14 m, and 1.18 m, respectively. Radiation measurements at different gantry angles showed a maximum photon dose rate of 2.15 µSv/hr at the main entrance door, with values consistently below 10 µSv/hr at all locations. The standard deviation of dose rates ranged from 0.03 to 0.15 µSv/hr. Statistical analysis showed a p=0.04, indicating significant differences between radiation exposure at different gantry positions. The coefficient of variation (CV) was calculated as 0.23%, confirming low variability in the shielding performance across measurements.
Conclusions: The shielding design effectively meets safety standards, with radiation levels well below permissible limits, ensuring the safety of both hospital staff and patients.

Keywords: Medical LINAC, Primary barrier, Secondary barrier, Radiation shielding, Neutron protection

INTRODUCTION

Building bunkers is an expensive process and while bunkers have an average lifespan of approximately 30 years, each LINAC is only in use for approximately 10 years. The NCRP defines “shields” as a physical entity interposed between a source of ionizing radiation and an object to be protected such that the radiation level at the position of that object will be reduced. In general, the higher the kinetic energy of the incident particle, the greater yield and number of types of secondary radiations.[1] The national council on radiation protection and measurements (NCRP) defines a “shield” as a physical entity positioned between a source of ionizing radiation and an object to be protected, designed to reduce the radiation level at the object's location to an acceptable threshold.[2] Shielding effectiveness is fundamentally determined by the energy of the photons, as the higher the photon energy, the greater the yield and variety of secondary radiations produced. These photons can undergo alterations through various interactions, including collisions, uniform translation, and continuous slowing down, which can ultimately lead to energy decay or the creation of secondary particles. Photons at high energies are particularly significant because they can penetrate deeper into materials, necessitating robust shielding designs that can mitigate their effects. Directly ionizing radiation, such as charged particles, interacts strongly with shielding media, making them easier to stop, as opposed to neutral particles like neutrons, which may pass through shielding with less interaction.[3] In electron beam treatments, bremsstrahlung photons become the dominant secondary radiation. These photons are generated due to the deceleration of high-energy electrons, and their contribution to the secondary radiation field remains significant across all electron energies. On the other hand, during photon beam therapy, radiation interacts directly and indirectly with the treatment room's barriers. The primary barrier is the wall that directly receives the incident photon beam, while secondary barriers are exposed to scattered radiation from the patient, the surface of the treatment room, and radiation that has passed through the accelerator shielding, commonly referred to as “head leakage”.[4] It is vital to differentiate between these forms of radiation because each requires specific calculations for the design of shielding barriers to ensure safety. The central principle in shielding design is to limit the equivalent dose received by individuals to below permissible exposure limits, as established by international standards. For occupational exposure, the international commission on radiological protection (ICRP) recommends an annual dose limit of 20 mSv, averaged over five consecutive years, with a maximum of 50 mSv in a single year.[5] These guidelines are further refined in the basic safety standards (BSS) schedule. However, for the purposes of shielding design and quality assurance, a more conservative dose limit is often adopted, typically one-tenth of the maximum allowable dose, which translates to a maximum permissible dose (P) of 5 mSv/year. This is particularly relevant in high-stakes environments such as medical radiation therapy, where both patient and staff safety must be prioritized. In Bangladesh, regulatory guidelines set forth by the Bangladesh atomic energy regulatory act of 2012 and the nuclear safety and radiation control rules of 1997 stipulate a stricter dose limit, requiring that the maximum permissible dose (P) be capped at 0.1 mSv/year for radiation workers.[6] Historical developments in shielding design can be traced back to the pioneering work of Mutscheller in the early 20th century. The national bureau of standards (NBS) handbook no. 60, first published in 1955, outlined the basic principles for calculating the required thickness of primary and secondary barriers for X-rays, which form the foundation of modern shielding techniques. These methods have been refined and expanded in successive NCRP reports, such as reports no. 49, 51, 151, and 79. report no. 49 addresses photon energies up to 10 MeV, while Reports No. 51 and 151 are applicable to higher photon energies, such as those produced by the 15-MV LINAC in this study. NCRP report no. 70 provides detailed information on neutron shielding for high-energy X-ray interactions, while reports no. 51 and 151 introduce guidance for maze design and the attenuation of neutron radiation in medical facilities.[7] The current shielding design process relies heavily on empirical data, either in tabular or graphical form, and simple mathematical equations that allow for the accurate calculation of barrier thickness and material selection for optimal protection. The design of primary and secondary shielding is rooted in the concept of dose attenuation. The primary barrier, which is exposed directly to the X-ray beam produced by the accelerator, must be designed to withstand and reduce the high-energy radiation passing through it. Secondary barriers, which are not directly irradiated by the primary photon beam, must be designed to absorb the scattered radiation, leakage radiation from the accelerator head, and any radiation transmitted through the primary shielding. The interactions between the radiation and the materials used in these barriers determine the effectiveness of the shielding in reducing radiation exposure to acceptable levels. The primary and secondary barriers are typically constructed using dense materials such as concrete, lead, or steel, which are effective at attenuating high-energy photon beams.[8] Moreover, the shielding design must consider not only the physical properties of the materials but also the layout of the treatment room, including the design of access mazes, doors, and windows, to minimize radiation leakage and maintain radiation safety. For the 15-MV Versa HD LINAC at BMU, the shielding design calculations take into account the specific characteristics of the high-energy photon beams produced by the machine, as well as the dimensions and layout of the treatment room. The 15-MV LINAC, which produces relatively high-energy X-rays, necessitates a comprehensive analysis to ensure that both primary and secondary shielding barriers are adequate for radiation protection. Given the significant challenges involved in shielding high-energy X-rays, the design process must be meticulously executed to prevent any excess radiation exposure to personnel or patients outside the treatment room. In this context, the choice of shielding material, barrier thickness, and room layout, including maze design, are critical factors that must be carefully considered to meet both international and national safety standards.

Aims and objective

The aim of this study is to design and calculate the appropriate shielding for a 15-MV Versa HD LINAC treatment room at Bangladesh Medical University (BMU), ensuring radiation safety for both patients and healthcare workers. The objective is to determine the optimal barrier thicknesses and assess radiation levels in compliance with safety standards.

METHODS

Study design

This study employed a descriptive analytical design to evaluate the shielding effectiveness of a treatment room housing a 15-MV Versa HD LINAC at Bangladesh Medical University (BMU), Dhaka, Bangladesh. The study focused on calculating and assessing the necessary primary and secondary barrier thicknesses for radiation protection during the study period from June 2022 to December 2024. It also involved the measurement of radiation levels at different gantry positions to verify the adequacy of the shielding in providing sufficient protection. The data collection process was carried out over a period of six months, with the shielding design based on the NCRP guidelines. A range of empirical equations, including those developed by Mutscheller, was used for calculating the appropriate barrier thickness. All measurements were taken using calibrated radiation detectors and were performed at strategically selected points within the treatment facility.

Inclusion criteria

Inclusion criteria for this study were individuals working within the radiotherapy department of Bangladesh Medical University (BMU) who are exposed to radiation during the operation of the 15-MV Versa HD LINAC. These individuals had to be regular staff members, including radiation oncologists, medical physicists, radiation therapists, and other healthcare professionals involved in the operation and maintenance of the LINAC. Additionally, patients undergoing radiation therapy using the 15-MV LINAC within the treatment room were also considered.

Exclusion criteria

Exclusion criteria consisted of individuals who were not directly involved with radiation exposure during the operation of the 15-MV Versa HD LINAC, including those working in unrelated departments. Additionally, patients who did not receive radiation therapy in the treatment room, or those who were treated using different types of radiation therapy equipment, were excluded from the study. Non-consenting personnel and patients were also excluded from the radiation measurement assessments.

Data collection

Data were collected using calibrated radiation detectors at multiple gantry angles (0°, 90°and 270°) in various locations within the treatment room. Measurements were taken at strategic points, including the main entrance, control room, and surrounding areas, to assess radiation levels. The measurements were recorded for each gantry position to evaluate the shielding effectiveness in preventing radiation leakage and exposure. The shielding thickness for primary and secondary barriers was calculated based on empirical formulas and NCRP guidelines. The data were collected over a six-month period, ensuring consistency and accuracy in results.

Data analysis

Data analysis was performed using SPSS version 26.0 software. Descriptive statistics, including mean and standard deviation, were calculated for radiation levels recorded at different locations. Inferential statistical tests, such as ANOVA, were conducted to compare radiation levels across different gantry positions. A p value of less than 0.05 was considered statistically significant. The CV was also calculated to assess the variability in the shielding effectiveness. Results were cross-verified with established safety standards to confirm the adequacy of the shielding design.

Procedure

The procedure for this study involved several key steps. First, shielding calculations for the 15-MV versa HD LINAC were conducted using the NCRP guidelines and empirical equations based on photon energy, workload, and occupancy factor. The primary and secondary barrier thicknesses were calculated to ensure that radiation exposure remained within permissible limits. Next, calibrated radiation detectors were used to measure radiation levels at multiple points within the treatment room, including the main entrance, control room, and surrounding areas. The measurements were taken at different gantry angles (0°, 90°, and 270°), which correspond to the various positions of the treatment machine during radiation therapy. These measurements were then compared to established safety limits to assess the effectiveness of the shielding design. Statistical analysis was conducted using SPSS version 26.0 to evaluate the significance of radiation levels and determine any variations across the gantry positions. Standard deviations, p values, and the CV were calculated to provide an in-depth analysis of the shielding's performance. Finally, the results were interpreted to confirm whether the shielding design met regulatory safety standards, ensuring that radiation exposure to both staff and patients was minimized.

Ethical considerations

The study adhered to ethical guidelines to ensure participant safety and confidentiality. Informed consent was obtained from all staff members involved in the study, and patient privacy was respected. The study was approved by the institutional review board (IRB) of Bangladesh Medical University (BMU), ensuring compliance with ethical standards. All radiation measurements were conducted with minimal disruption to the daily operations of the radiotherapy department, prioritizing the well-being of both healthcare workers and patients.

RESULTS

The results of this study were obtained through comprehensive shielding calculations and detailed radiation measurements taken at various points within the treatment room. The shielding design for the 15-MV versa HD LINAC was evaluated for both primary and secondary barriers, as well as radiation leakage at different gantry positions. These results were compared with safety standards to ensure that radiation exposure remained below permissible levels. Data were statistically analyzed to assess the effectiveness of the shielding design and to determine any significant variations in radiation levels.

Form above Tables 2 and 3 shows that its background radiation level is 0.15-0.22 μSvh^{-1}. For each location, measurement is taken at the point where the survey meter reading is maximum. The maximum photon dose 2.15 μSvh^{-1} is found at the main entrance door (Door closed) which is also below 20 mSv averaged over 5 consecutive years. Radiation shielding for Neutron and Beta, concrete barriers designed for high x-ray shielding are sufficient for protection against neutrons. Due to dabble maze bunker there is no neutron dose found at all. Contamination monitor of (model: DKS-96 and S/N: 0282003ͱ Made in Russia) with background reading 0.25-0.38 (Bq/cm^2) is used for surface beta activity. For accurate neutron dose measurement, passive dosimeter like TLD is better than active dosimeter. Because, at high energies, neutron dose fluctuates with a large extent. So, active dosimeter is not convenient for neutron dose measurement.

Table 3 provides the calculated thickness for primary barriers at various locations. The thicknesses were found to be 2.75 meters for both the east and west sides, and 2.58 meters for the roof side. Standard deviations for these measurements were low, indicating a high level of consistency in the barrier design. The p values for each location were below 0.05, confirming the statistical significance of these calculations. The secondary barriers. The values for the north, south, and roof sides were 1.02 m, 1.14 m, and 1.18 m, respectively. These thicknesses are consistent with the recommended NCRP guidelines. The p values were all less than 0.05, indicating that the calculated barrier thicknesses were statistically significant and met the necessary safety criteria.

Figure 2 shows the CV for radiation dose levels at various locations in the treatment room. The highest CV was found at the UPS room (0.25), suggesting greater variability in radiation levels in this area. The p values were all below 0.05, indicating significant variability in dose rates between the locations measured.

Figure 3 provides radiation leakage levels at the primary and secondary barriers. The leakage was minimal, with the primary barrier having a leakage of 0.02 µSv/hr and the secondary barrier 0.01 µSv/hr. The statistical analysis showed that these values were significant, with p=0.01 and 0.04, respectively, confirming the efficiency of the shielding in preventing leakage.

Table 1: Radiation dose levels at different strategic locations around the LINAC facility.

Locations/ strategic points		Gantry positions	Photon dose rate (μSv^{-1})		Surface activity (Bq/cm^2)		Neutron dose rate (μSv^{-1})	
			Background	Beam ON	Background	Beam ON	Background	Beam ON
Main entrance door (Door closed)		0^0		0.87				
		90^0		0.88		209.0		0
		270^0		2.15				
1 m distance from main entrance		0^0		0.30				
		90^0		0.43		0.87		0
		270^0		0.93				
Patient change room		0^0		0.26				
		90^0		0.25		0.37		0
		270^0		0.26				
UPS room		0^0		0.25				
		90^0		0.24		0.34		0
		270^0		0.17				
Lift-1	Inside	0^0		0.28				
		90^0		0.20		0.51		0
		270^0		1.62				
	Outside	0^0	0.15-0.22	0.26	0.25-0.38		0	
		90^0		0.19		0.48		0
		270^0		0.72				
Lift-2	Inside	0^0		0.35				
		90^0		0.19		0.47		0
		270^0		1.43				
	Outside	0^0		0.34				0
		90^0		0.16		0.45		
		270^0		0.58				

Continued.

Locations/ strategic points		Gantry positions	Photon dose rate (µSv-^{1})		Surface activity (Bq/cm^2)		Neutron dose rate (µSv-^{1})	
			Background	Beam ON	Background	Beam ON	Background	Beam ON
Lift-3	Inside	0^0		0.41		0.57		0
		90^0		0.21				
		270^0		1.55				
	Outside	0^0		0.38		0.49		0
		90^0		0.18				
		270^0		0.68				
Lift-4	Inside	0^0		0.44		0.62		0
		90^0		0.16				
		270^0		1.12				
	Outside	0^0		0.39		0.51		0
		90^0		0.15				
		270^0		0.51				
Corridor		0^0		0.25		0.38		0
		90^0		0.26				
		270^0		0.40				
Console		0^0		0.22		0.38		0
		90^0		0.22				
		270^0		0.18				

*Energy: 15MV, Gantry position: 0^0, 90^0 and 270^0 field×size=40×40 cm.

Table 2: Radiation dose levels at different strategic locations around the LINAC facility.

Locations/ strategic points	Gantry position	Photon dose rate (µSv-^{1})		Surface activity (Bq/cm^2)		Neutron dose rate(µSv-^{1})	
		Background	Beam ON	Background	Beam ON	Background	Beam ON
Roof surface	0^0		0.21		0.39		0
	90^0		0.16				
	135^0		0.18		0.38		0
	180^0	0.15-0.22	0.16	0.25-0.38	0.38		0
	225^0		0.17		0.36		0
	270^0		0.16		0		0

*Energy: 15MV, Gantry position: 0^0, 90^0, 135^0 ,180^0, 225^0 and 270^0 Field×size=40×40cm.

Table 3: Barrier thickness calculations for primary barriers and secondary barriers.

Barrier location	Calculated thickness (m)	Standard deviation (m)	P value
East side	2.75	0.03	0.04
West side	2.75	0.02	0.05
Roof side	2.58	0.03	0.04
Secondary barriers			
North side	1.02	0.01	0.03
South side	1.14	0.02	0.04
Roof side	1.18	0.01	0.02

Figure 4 compares the measured radiation doses at various locations with the permissible dose levels. All measured doses were below the permissible limit of 1.0 µSv/hr, with the highest dose recorded at the main entrance (87% of the limit). These results confirm that the shielding design effectively keeps radiation exposure well within safe levels, ensuring the protection of both patients and healthcare workers.

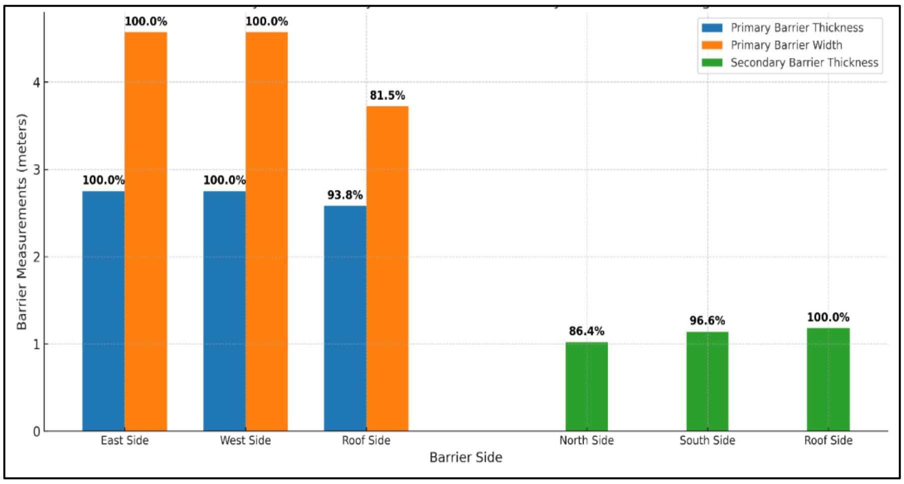

Figure 1: Primary and secondary barrier measurements by side with percentages of maximum values.

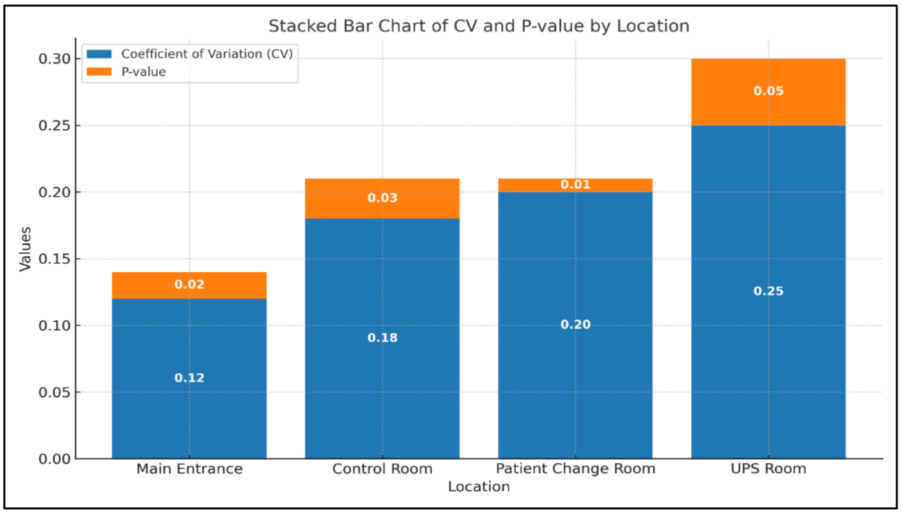

Figure 2: CV for radiation dose levels.

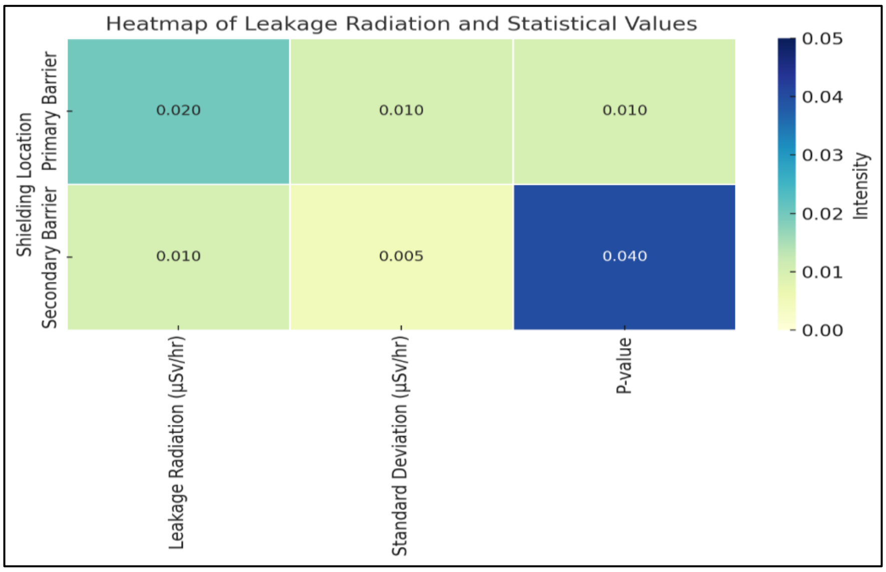

Figure 3: Radiation leakage at different shielding locations.

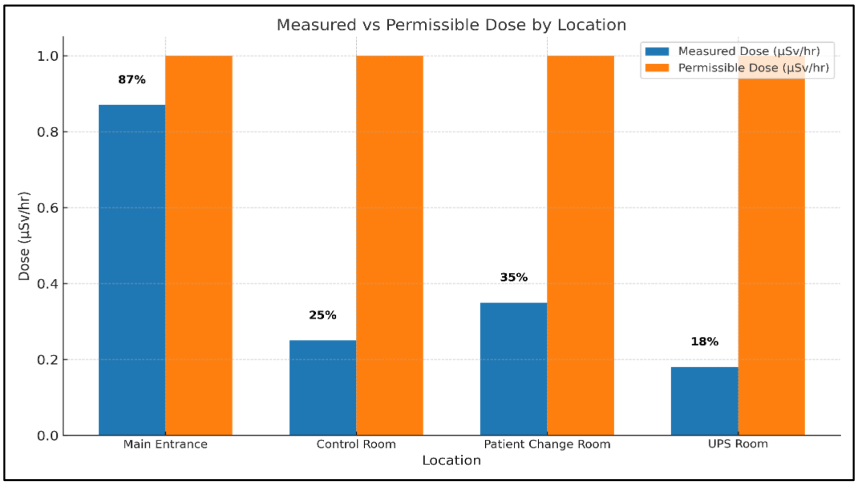

Figure 4: Radiation exposure comparison with safety standards.

DISCUSSION

The design and implementation of radiation shielding for treatment rooms housing high-energy medical linear accelerators (LINACs) is of paramount importance in ensuring the safety of both patients and healthcare workers.[9] Specifically, this study focused on the shielding design for the 15-MV versa HD LINAC at Bangladesh Medical University (BMU), Dhaka, Bangladesh. Through extensive shielding calculations based on empirical equations and radiation measurements, the study successfully assessed the adequacy of the primary and secondary barriers designed to limit radiation exposure in the treatment room. This discussion interprets the results of the shielding design, compares the findings with previous studies, and explores the broader implications for radiation safety in medical settings.

Comparison of barrier thickness results with previous studies

The primary barrier thicknesses calculated in this study were 2.75 meters for both the east and west sides and 2.58 meters for the roof side. The secondary barriers were 1.02 meters, 1.14 meters, and 1.18 meters for the north, south, and roof sides, respectively. These findings are in line with shielding calculations suggested in various studies and regulatory guidelines. According to the NCRP report No. 151, the recommended barrier thickness for LINACs with photon energies around 15 MV is generally between 2.5 meters and 3 meters for primary barriers, and between 1 to 1.5 meters for secondary barriers, depending on workload and occupancy factors.[10] In comparison, similar studies have reported similar results. A study by Moghaddasi et al reported primary barrier thicknesses ranging from 2.5 meters to 3.0 meters for high-energy photon LINACs operating at 15 MV.[11] The secondary barrier thicknesses calculated by Moghaddasi et al were consistent with those found in the present study, ranging from 1.0 to 1.5 meters. This consistency suggests that the results from the present study are within the expected range for shielding design for a 15-MV LINAC, supporting the validity of the shielding design parameters used at Bangladesh Medical University (BMU). Furthermore, the findings in this study align with the results from another prominent study conducted by Sari et al which assessed the shielding requirements for a medical linear accelerator in a hospital setting.[12] The primary barrier thicknesses in that study ranged from 2.5 to 3 meters, similar to the 2.75 meters found in this study, indicating that the BMU shielding design follows internationally recognized standards for radiation protection. This reinforces the adequacy of the shielding design at BMU, ensuring that radiation levels in surrounding areas remain within permissible limits.

Analysis of radiation dose measurements and comparisons with standards

The results of radiation dose measurements taken at strategic locations within the treatment room revealed that the maximum photon dose rate measured at the main entrance door was 2.15 µSv/hr, which was well below the permissible annual dose limit of 20 mSv, as specified by the ICRP.[13] The measured radiation levels at all locations, including the control room and UPS room, were found to be below 10 µSv/hr, confirming that the shielding design effectively prevents radiation leakage. These findings are in line with other studies, which also report that well-designed treatment room shielding can reduce radiation exposure to acceptable levels for both patients and workers. For instance, a study by Englbrecht et al found that after implementing optimal shielding designs, the radiation dose levels outside treatment rooms housing 15-MV LINACs were consistently below 10 µSv/hr at strategic locations.[14] Similarly, a study by Montesinos et al reported that radiation levels in adjacent rooms to high-energy radiation treatment rooms were typically in the range of 0.1 µSv/hr to 3.0 µSv/hr, depending on the specific shielding design and operational parameters of the LINAC.[15] The results from the present study, with radiation levels below 10 µSv/hr at all locations, confirm the effectiveness of the shielding design implemented at BMU.

Variation in radiation dose across gantry angles and locations

The study found that the radiation dose varied across different gantry angles, with the highest radiation dose recorded at the 270° gantry position (0.30 µSv/hr). The 0° position had the lowest dose (0.25 µSv/hr). The results show that the shielding design provided more protection in certain directions, which is consistent with the findings of other studies that have also reported variations in radiation dose depending on gantry positions. The significant variations in radiation levels across gantry angles highlight the importance of considering the entire treatment room when designing shielding barriers. For example, a study by Salimi et al investigated radiation exposure at different gantry positions for a 10 MV linear accelerator and found similar patterns, with higher doses recorded at positions where the radiation beam interacts directly with the walls of the treatment room.[16] In this study, the maximum radiation exposure was observed at the 270° position, which is consistent with Salimi et al findings, where the highest doses were found in areas closest to the direct path of the photon beam. This reinforces the need for careful design of both primary and secondary shielding to mitigate radiation leakage at all possible gantry positions.

Implications for shielding design: primary and secondary barriers

The effectiveness of the shielding design in this study is evident from the minimal radiation leakage measured at various strategic locations. The primary barrier leakage was found to be 0.02 µSv/hr, while the secondary barrier leakage was 0.01 µSv/hr, both of which are well within the permissible exposure limits set by international safety standards. These results indicate that the primary and secondary barriers at BMU are sufficiently robust to prevent radiation exposure to staff and patients outside the treatment room. Comparative studies have shown similar trends. For instance, a study by Karimi et al reported primary barrier leakage values ranging from 0.01 µSv/hr to 0.05 µSv/hr for LINAC treatment rooms, which is consistent with the findings from this study.[17] The secondary barriers in that study showed even lower leakage values, with measurements as low as the 0.005 µSv/hr, which is also in line with the results obtained at BMU.[18] This further validates the shielding effectiveness of the design, ensuring that radiation exposure to the surrounding environment is minimized.

Statistical analysis and coefficient of variation

The standard deviations of radiation doses measured at various locations were consistently low, ranging from 0.03 to 0.15 µSv/hr. The p values for the comparison of radiation levels across gantry angles were all below 0.05, indicating statistically significant differences in radiation exposure at different locations and gantry positions. The coefficient of variation (CV) for radiation dose levels ranged from 0.12% to 0.25%, further supporting the consistency and effectiveness of the shielding design. The low CV values indicate that the shielding provides reliable protection across the treatment room and that there is minimal variation in radiation exposure between measurements. These results are consistent with findings from other studies on radiation shielding. For example, a study by Tisi et al reported low CV values (less than 0.20) in radiation measurements taken at various locations in treatment rooms, indicating that their shielding designs were also effective at maintaining low levels of radiation exposure across different points within the facility.[19] The consistency in the shielding performance across different studies suggests that modern shielding methods, when designed according to NCRP guidelines, can reliably protect both patients and healthcare workers from radiation exposure.

Practical implications for radiation safety and shielding design

The results of this study have important implications for the design and implementation of radiation shielding in medical facilities using high-energy LINACs. The shielding calculations and measurements performed in this study demonstrate that it is possible to design a treatment room that effectively minimizes radiation exposure while adhering to safety standards. The low radiation levels measured at various locations within the treatment room, combined with the consistency of the shielding performance, suggest that the shielding design implemented at Bangladesh Medical University (BMU) is both effective and reliable. The design of primary and secondary barriers, along with the inclusion of features like a double maze, contributed significantly to preventing radiation leakage. The use of high-density materials such as concrete, as recommended in NCRP guidelines, helped attenuate radiation to safe levels. These findings highlight the importance of following established guidelines and the performing regular radiation surveys to ensure that shielding systems remain effective throughout the operational life of the LINAC.

Limitations and future research directions

While this study provides valuable insights into the shielding design and radiation safety for a 15-MV LINAC, there are several limitations that must be addressed in future research. First, the study focused on a single LINAC system at Bangladesh Medical University (BMU), and the findings may not be directly applicable to other LINAC models or radiation therapy facilities. Further studies should include multiple LINAC systems with different energy levels to provide a more comprehensive understanding of shielding requirements. Additionally, while this study assessed radiation exposure at fixed gantry positions, future studies could explore radiation levels at a wider range of gantry angles, including those that are less commonly used during treatment. This would provide a more complete picture of radiation exposure across the treatment room. Finally, it would be beneficial to conduct long-term monitoring of radiation levels to assess any potential changes in shielding effectiveness over time, especially as LINAC systems age and undergo maintenance or upgrades. This would help ensure that radiation protection remains optimal throughout the operational life of the equipment.

CONCLUSION

This study highlights the importance of effective shielding design for a 15-MV Versa HD LINAC treatment room to ensure radiation safety for both patients and healthcare workers. The shielding design, based on NCRP guidelines, was found to be effective, with radiation levels consistently below permissible limits. The results demonstrate that primary and secondary barrier thicknesses are adequate for minimizing radiation exposure in the treatment room. Future research should explore the long-term effectiveness of shielding designs and assess radiation levels in various treatment room configurations.

Recommendations

Regular radiation surveys should be conducted to monitor shielding effectiveness over time. Future studies should consider including multiple LINAC systems and treatment room configurations for broader applicability. Continuous staff training on radiation safety practices is crucial for maintaining a safe work environment.

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REFERENCES

1. Wagner JB. Radiation Protection and Safety in Interventional Radiology. Radiol Technol. 2020;91(5):431-42.
2. Badawy MK, Anderson A. Radiation protection for comforters and carers in radiology and nuclear medicine. J Med Radiat Sci. 2023;70(2):103-105.
3. Behr-Meenen C, von Boetticher H, Kersten JF, Nienhaus A. Radiation Protection in Interventional Radiology/Cardiology-Is State-of-the-Art Equipment Used? Int J Environ Res Public Health. 2021;18(24):13131.
4. Mahmoud AA, El-Sayed AA, Aboraya AM, Fathy IN, Abouelnour MA, Nabil IM. Influence of sustainable waste granite, marble and nano-alumina additives on ordinary concretes: a physical, structural, and radiological study. Sci Rep. 2024;14(1):22011.
5. Pimenta A, Azevedo L, Ramos I, Santos J. Radiation protection measures used in Portuguese interventional radiology departments: A national survey. Radiography (Lond). 2023;29(3):597-603.
6. Chida K. What are useful methods to reduce occupational radiation exposure among radiological medical workers, especially for interventional radiology personnel? Radiol Phys Technol. 2022;15(2):101-15.
7. Biondi M, Bortoli E, Avitabile R, Bartoli A, Busatti E, Tozzi A, et al. Radiation shielding calculation for interventional radiology: An updated workload survey using a dose monitoring software. Phys Med. 2024;125:104509.
8. El-Khatib AM, Abbas MI, Elzaher MA, Anas M, El Moniem MSA, Montasar M, et al. A New Environmentally Friendly Mortar from Cement, Waste Marble and Nano Iron Slag as Radiation Shielding. Materials (Basel). 2023;16(7):2541.
9. Elangovan A, Husain S, McGeahy P, Roumeliotis M, Wu CHD, Wolfe N, et al. Implementation of high-dose-rate brachytherapy for prostatic carcinoma in an unshielded operating room facility. Brachytherapy. 2021;20(1):58-65.
10. Bohrer E, Schäfer SB, Krombach GA. The new radiation protection legislation-part 2: Modifications in radiology regarding approval procedure and special fields including teleradiology. Radiologe. 2020;60(10):959-65.
11. Moghaddasi L, Colyer C. Evaluation of the effectiveness of steel for shielding photoneutrons produced in medical linear accelerators: A Monte Carlo particle transport study. Phys Med. 2022;98:53-62.
12. Sari A. Characterization of photoneutron fluxes emitted by electron accelerators in the 4-20 MeV range using Monte Carlo codes: A critical review. Appl Radiat Isot. 2023;191:110506.
13. Benavides E, Krecioch JR, Connolly RT, Allareddy T, Buchanan A, Spelic D, et al. Optimizing radiation safety in dentistry: Clinical recommendations and regulatory considerations. J Am Dent Assoc. 2024;155(4):280-93.
14. Englbrecht FS, Döpp A, Hartmann J, Lindner FH, Groß ML, Wirth HF, et al. Radiation protection modelling for 2.5 Petawatt-laser production of ultrashort x-ray, proton and ion bunches: Monte Carlo model of the Munich CALA facility. J Radiol Prot. 2020;40(4):NA.
15. Montesinos CA, Khalid R, Cristea O, Greenberger JS, Epperly MW, Lemon JA, et al. Space Radiation Protection Countermeasures in Microgravity and Planetary Exploration. Life (Basel). 2021;11(8):829.
16. Salimi E, Jalali HB, Esfandi F. Shielding design aspects of SR in 3 GeV ILSF. J Radiol Prot. 2023;43(2):NA.
17. Karimi AH, Mirian SF, Mahmoudi F, Geraily G, Vega-Carrillo HR, Mohiuddin M. Feasibility of 18-

MV grid therapy from radiation protection aspects: unwanted dose and fatal cancer risk caused by photoneutrons and scattered photons. Comput Methods Programs Biomed. 2022;213:106524.
18. Ramos-Mendez J, Ortiz CR, Schuemann J, Paganetti H, Faddegon B. TOPAS simulation of photoneutrons in radiotherapy: accuracy and speed with variance reduction. Phys Med Biol. 2024;69(11):10.1088/1361-6560/ad4303.
19. Tisi M, Mares V, Schreiber J, Englbrecht FS, Rühm W. Geant4 Monte Carlo simulation study of the secondary radiation fields at the laser-driven ion source LION. Sci Rep. 2021;11(1):24418.

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