AN INTERCONTINENTAL RADIATION SAFETY PARTNERSHIP: SHIELDING DESIGN FOR A PRIVATE RADIOTHERAPY CENTER IN MOMBASA, KENYA

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Abstract— **Access to radiotherapy remains a stark global disparity, with over 90% of the population in low-income countries (LICs) lacking treatment options. Nowhere is this challenge more pressing than in sub-Saharan Africa, where a critical shortage of medical physicists compounds the problem. While the roots of this inequity are complex, one avenue for immediate impact is leveraging the expertise of physicists in high-income countries (HICs) to support capacity-building efforts in LICs. This work presents a roadmap for an intercontinental radiation safety partnership, applied to the shielding design of a private radiotherapy center under construction in Mombasa, Kenya. The collaboration brought together three medical physicists from HICs, a health physicist in an LIC, and a medical physics trainee in that same LIC tasked with overseeing the shielding calculations for two treatment vaults: one housing an Elekta Versa HD linear accelerator and another for an Elekta Flexitron high-dose rate (HDR) brachytherapy afterloader. Shielding calculations followed established protocols from NCRP report 151, ensuring compliance with radiation protection standards. Minimum concrete thicknesses were determined for all barriers, safeguarding both patients and personnel. Additionally, the LIC physicists received training in shielding calculations, fostering local expertise and sustainability. As construction progresses, radiation surveys will validate the design. This structured collaboration offers a scalable model for physicists in HICs to support their counterparts in LICs, providing a tangible mechanism to address the global shortfall in radiotherapy access through knowledge exchange and technical partnership.**

Keywords— **Radiation safety, shielding, global health.**

I. INTRODUCTION

Cancer is an escalating crisis across sub-Saharan Africa, placing immense strain on already fragile healthcare systems [1]. In Kenya, where non-communicable diseases are steadily rising, cancer has established itself as the third leading cause of mortality, accounting for nearly 7% of annual deaths. Each year, approximately 40,000 new cases are diagnosed, and nearly 28,000 patients succumb to the disease [2]. These numbers are likely to increase dramatically in the coming decades as risk factors such as urbanization, environmental exposures, changing dietary habits, and aging populations take hold [3]. Yet, despite its growing prevalence, cancer control remains limited by systemic barriers: late-stage diagnoses, a severe shortage of oncologists and medical physicists, financial constraints, and an absence of widespread treatment infrastructure. More than 80% of cases in Kenya are diagnosed at advanced stages, when treatment options are limited and survival rates plummet. While there have been commendable efforts by the Kenyan Ministry of Health to address these challenges—through initiatives such as the National Cancer Control Strategy and the expansion of public insurance coverage for cancer treatment—progress has been hindered by inadequate resources and a lack of trained personnel [4].

Among the most pressing gaps in cancer care is the limited availability of radiotherapy, a treatment modality that plays a vital role in both curative and palliative cancer management [5]. Globally, radiotherapy is estimated to be required in about 50% of all cancer cases [6], yet in many low-income countries, access is severely constrained. Kenya currently has only a handful of radiotherapy centers, mostly concentrated in major urban areas, leaving sizable portions of the population without access to timely and effective treatment. Patients from rural areas often must travel hundreds of kilometers to the nearest facility, incurring significant financial burdens that force many to abandon treatment altogether. Even in urban centers where radiotherapy is available, long waiting times, outdated machines, and shortages of trained personnel make timely care a persistent challenge. While public hospitals remain the primary providers of radiotherapy, private centers serve an important complementary role, helping to absorb patient demand and alleviate treatment delays. These facilities, often more responsive to technological advancements and infrastructure development, provide an alternative for those who might otherwise face months-long wait times in government hospitals. However, in public hospitals, treatment delays can extend for months, while private institutions can be prohibitively expensive for most patients [7]. The consequence of these challenges is not just a high cancer mortality rate but a devastating impact on families and communities, where lost productivity and financial ruin compound the suffering of the disease itself [8].

Expanding radiotherapy infrastructure is therefore a critical component of Kenya's broader cancer control strategy. However, with this expansion comes the responsibility of ensuring radiation safety [9]—an aspect of radiotherapy implementation that is often overlooked in discussions about increasing access. Radiation used in cancer treatment, if not properly accounted for, poses a risk not only to patients but also to healthcare workers and members of the public [10]. Poorly designed shielding can lead to unnecessary exposure, increasing the likelihood of long-term radiation-induced health effects. International guidelines, such as those outlined in the International Atomic Energy Agency's (IAEA) SRS-47 or the National Council on Radiation Protection and Measurements' (NCRP) Reports 49 and 151, establish stringent requirements for shielding design in radiotherapy facilities, ensuring that radiation exposure remains within permissible limits for occupational workers and the general public [11-13]. Achieving these safety standards requires specialized expertise in medical physics [14], yet Kenya—like many low-income countries—faces a chronic shortage of trained physicists [15]. Without adequate physics support, new radiotherapy facilities run the risk of suboptimal shielding, exposing healthcare workers and surrounding populations to unintended radiation doses. Thus, capacity-building efforts in medical physics are not only a technical necessity but a fundamental component of sustainable radiotherapy expansion [16].

Recognizing these challenges, we present herein a structured roadmap for an intercontinental medical physics collaboration, applied specifically to the shielding design of a private radiotherapy center under construction in Mombasa, Kenya. This initiative brought together medical physicists from high-income countries (HICs), a health physicist from Kenya, and a medical physics trainee from Kenya, working jointly to ensure that the facility's shielding design adheres to international radiation protection standards. The collaboration focused on calculating the necessary concrete thicknesses for two treatment vaults: one housing an Elekta Versa HD linear accelerator and the other an Elekta Flexitron high-dose rate (HDR) brachytherapy afterloader. The calculations were performed following the formalism outlined in NCRP Report 151, ensuring that all protective barriers met the required shielding standards [13]. Beyond the technical outcomes, this partnership served a dual purpose—designing a safe and effective radiotherapy facility while also building local expertise. The Kenyan physicists were trained in shielding calculations, enabling them to apply these skills to future projects and contribute to the long-term growth of Kenya's radiotherapy infrastructure.

This work attempts to provide a replicable model for future collaborations aimed at addressing the medical physics capacity gap in low-income countries (LICs). By leveraging the expertise of physicists in HICs, such partnerships can help bridge the knowledge divide, equipping LIC physicists with the skills and resources necessary to support the safe expansion of radiotherapy services. As construction of the Mombasa facility progresses, radiation surveys will validate the shielding calculations, serving as a crucial quality assurance step before patient treatments begin. Moving forward, similar collaborative frameworks can be implemented across other regions lacking in sufficient medical physics capacity where radiotherapy access remains constrained, ensuring that expansion efforts prioritize not just availability but also safety [17]. In this way, structured partnerships between HIC and LIC physicists offer a tangible mechanism for mitigating global disparities in radiotherapy access, providing a foundation for equitable cancer treatment worldwide.

II. MATERIALS AND METHODS

A radiotherapy center, financed through private sector investment, is currently under construction in Mombasa, Kenya. The location of the center within Kenya is illustrated in Figure 1. To ensure appropriate radiation shielding for the facility, the owners engaged a local health physicist to conduct the shielding design calculations. However, the health physicist, while experienced in radiation protection, lacked formal training in radiotherapy shielding design. Recognizing the complexity of the task, the physicist sought guidance from qualified medical physicists based in a HIC to assist in the shielding process. This collaboration provided not only technical expertise but also an opportunity for structured knowledge transfer, equipping the local physicist with the skills necessary to perform similar calculations in the future.

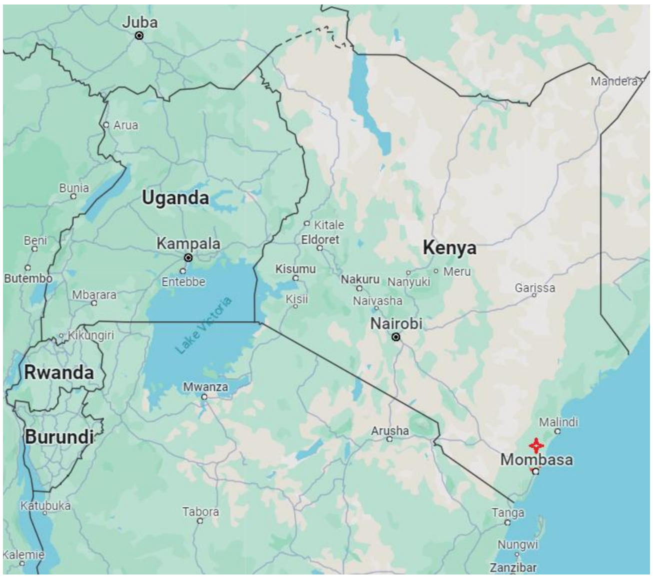

Figure 1: Geographic location of the private radiotherapy center (marked by a red star) where radiation safety services were provided, both within Kenya across the East African region

The facility will house two treatment vaults: one designated for a medical linear accelerator (linac) and the other for a high-dose rate (HDR) brachytherapy afterloader. A snapshot of the architectural layout of the facility is provided in Figure 2. The linear accelerator will be equipped with photon energy modes of 6 MV and 18 MV. The HDR service intends to use Ir-192 sources; however, due to the uncertainty of Ir-192 availability, the HDR vault shielding was conservatively designed assuming the use of Co-60. All shielding calculations were performed with the assumption that standard-density concrete would be used as the shielding material.

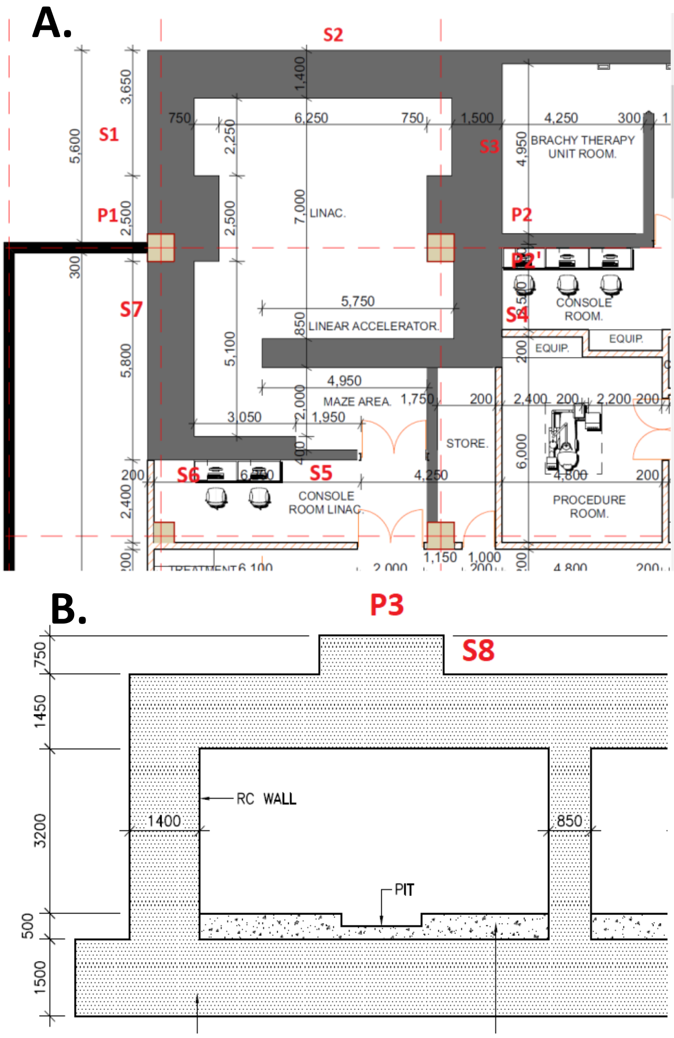

Figure 2: Architectural design of the linear accelerator vault from a top-down perspective (2A.) and sectional perspective (2B.) – The primary and secondary barriers are annotated (P vs. S).

For the linac vault, four primary barriers were initially identified. Since the vault is constructed directly on the ground floor with no occupied space beneath it, the floor barrier could be disregarded. Of the three remaining primary barriers, one was adjacent to two separate rooms with different occupancy factors. Because shielding requirements depend on occupancy, this barrier was treated as two distinct sections, P2 and P2', with separate calculations performed for each. The vault also included nine secondary barriers, two of which extended to a parking lot located on the floor above. The spatial distribution of these barriers is illustrated in Figure 2, where Figure 2A presents a cross-sectional view of the architectural design, and Figure 2B highlights the barriers positioned above the vault. Similarly, for the brachytherapy vault, five barriers were identified and included in the calculations: the four walls and the ceiling.

Shielding calculations were performed in accordance with the methodology outlined in NCRP Report 151 [13], which provides a standardized framework for determining the necessary thickness of protective barriers in megavoltage radiotherapy facilities. For each barrier, the transmission values (TVLs) for standard concrete were determined, followed by calculations of the required thickness to ensure that radiation exposure remained within permissible limits for occupational workers and the general public. Similar calculations were conducted for the HDR brachytherapy vault, with shielding requirements adapted to the lower energy emissions characteristic of brachytherapy sources.

This collaborative effort not only ensured that the shielding design adhered to international radiation protection standards but also served as a capacity-building initiative, allowing the local health physicist and a local medical physics trainee to gain hands-on experience with shielding calculations under expert guidance. Through this partnership, the project contributed to the broader goal of strengthening medical physics expertise in Kenya, fostering long-term sustainability in the safe expansion of radiotherapy services.

III. RESULTS

This collaborative process resulted in a comprehensive set of shielding design calculations ensuring that the radiotherapy facility meets international radiation protection standards while also fostering technical capacity development within Kenya's medical physics community. The shielding assessments covered both the linac vault and the HDR brachytherapy vault, with specific attention to primary and secondary barrier requirements for the linac vault calculations.

Table 1 Primary barrier shielding – linear accelerator vault

Primary Barrier	TVL's Needed	Concrete Needed (m)
P1	3.8	1.65
P2	4.4	1.91
P2'	4.7	2.04
P3	4.1	1.78

For the linac vault, shielding calculations were performed for the three primary barriers, taking into account the different occupancy factors where necessary. As detailed in Table 1, the required concrete thicknesses were determined based on workload, use factor, and occupancy classifications. The secondary barriers, including those on the floor above the treatment room, were similarly evaluated to ensure compliance with dose constraints for controlled and uncontrolled areas. The results of these calculations are summarized in Table 2. For the HDR vault, given the lower energy emissions compared to the linac, shielding requirements were correspondingly reduced, as shown in Table 3.

Table 2 Secondary barrier shielding – linear accelerator vault

Secondary Barrier	TVL's Needed (Scatter vs. Leakage)	Concrete Needed (m)
S1	2.8 / 2.1	1.22
S2	1.6 / 2.2	0.88
S3	3.4/ 2.7	1.47
S4	3.7 / 3.0	1.58
S5	2.2 / 2.8	1.09
S6	2.3 / 2.7	1.09
S7	2.8 / 2.1	1.22
S8	3.2 / 2.5	1.47
S9	1.7 / 2.3	1.47
Door	0.6/1.2	0.55

Table 3 Barrier shielding – HDR brachytherapy vault

Primary Barrier	TVL's Needed	Concrete Needed (m)
B1	2.5	0.36
B2	1.9	0.28
B3	2.7	0.40
B4	2.7	0.40
B5	1.1	0.16

Beyond the technical deliverables, this project served as a model for structured capacity building in medical physics. By engaging local professionals in the shielding process, the collaboration provided hands-on training in shielding calculations, bridging a critical knowledge gap in Kenya's radiotherapy expansion efforts. The health physicist who initiated the partnership and the medical physics trainee involved gained direct experience in applying NCRP 151 methodologies, reinforcing the principles of barrier design and radiation protection in high-energy radiotherapy environments. Through this knowledge exchange, the project contributed to strengthening Kenya's long-term ability to develop radiotherapy infrastructure safely and independently.

IV. DISCUSSION

This collaboration produced a shielding design that meets international radiation protection standards while supporting local capacity development in medical physics. Shielding calculations were performed using the formalism of NCRP Report 151 [13], incorporating site-specific parameters such as workload, occupancy, and structural constraints to ensure compliance with dose limits for both occupational workers and the public. These calculations represent a necessary prerequisite for safe radiotherapy operation and highlight the technical rigor required even at early stages of facility development.

As the facility advances toward clinical readiness, radiation surveys will be conducted to verify shielding performance prior to patient treatment. These surveys will be led by local physicists with remote support from international collaborators as needed [18]. This approach reinforces local ownership of safety-critical processes while maintaining access to external expertise during commissioning [19]. Successful completion of this phase will enable transition from construction to clinical operation.

Beyond the immediate technical outcomes, this project illustrates the importance of integrating workforce development into radiotherapy expansion efforts [20]. Kenya, like many low- and middle-income countries, continues to face a shortage of trained medical physicists [21-24]. Embedding hands-on training within the shielding design process provided practical experience with internationally accepted methodologies and helped address a critical skills gap. As radiotherapy capacity continues to expand nationally [25,26], such collaborative models may support safe implementation while contributing to longer-term sustainability.

V. CONCLUSIONS

Addressing the global shortfall in radiotherapy requires more than just increasing the number of treatment machines; it demands a parallel investment in the expertise needed to use them safely and effectively. This collaboration highlights a practical model for bridging the medical physics capacity gap in low-income countries, demonstrating how structured partnerships can provide both technical solutions and sustainable knowledge transfer. By involving local professionals in the shielding design process and providing hands-on training, this initiative not only ensured compliance with international safety standards but also contributed to building a more self-reliant medical physics workforce in Kenya. As the facility in Mombasa nears completion, the next phase of this work will focus on radiation surveys and ongoing mentorship to reinforce local expertise. While challenges remain in scaling such efforts more broadly, this project underscores the potential for collaborative models to play a meaningful role in expanding access to safe and effective radiotherapy in underserved regions.

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