

The Radiation Oncology Department: Design Guidelines, Implementation Challenges, and Lessons Learned in Thai Public Hospitals

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ABSTRACT

The radiation oncology department (ROD) is a specialized healthcare unit utilizing advanced radiation technologies to deliver precise cancer treatment, which demand complex coordination of space, safety, and multidisciplinary workflows. Although several ROD design guidelines exist, they are tailored to developed economies, remain piecemeal, and lack comprehensive feedback from practitioners in other socio-cultural conditions regarding their implementation process, difficulties, and outcomes. This research thus (1) synthesizes ROD design guidelines, (2) investigates the implementation challenges, and (3) collects insights and experiences from healthcare professionals involved in ROD operations. A mixed-method approach is employed, incorporating literature review, construction drawing analysis, site visits, and follow-up interviews. It reveals significant design and operational challenges, e.g., overcrowded waiting areas, limited spatial flexibility, constrained resources, differing workflow patterns, and context-specific user behaviors, complicating the direct application of international guidelines. It then offers tentative design guidance, e.g., zoning strategies aligned with treatment stages, flexible and sufficiently sized spaces, clear circulation routes separating staff and patient flows, spatial depth to support privacy and safety, and functional adjacencies that enhance procedural flow and interdisciplinary collaboration. This research serves as a foundation for context-responsive ROD design in Thailand and other similar settings. Future research should expand the case study pool, apply post-occupancy evaluations, explore patient experiences, and implement codesign models.

Keywords: healthcare architecture, hospital design, mixed-methods, patient experience, radiation oncology department

INTRODUCTION

The radiation oncology department (ROD) is a critical component of modern cancer care, utilizing advanced imaging and radiation technologies to deliver precise, targeted therapies and improve clinical outcomes (Kantarci et al., 2025). Its importance has grown alongside the rising global cancer burden. According to the World Health Organization [WHO] (2025), cancer remains one of the leading causes of death worldwide, responsible for nearly 10 million deaths in 2020. In Thailand, it has been the leading cause of mortality since 1999, with over 140,000 new cases and approximately 84,000 cancer-related deaths reported annually (Ministry of Public Health [MOPH], 2024). This growing prevalence affects individuals and families while imposing significant social and economic pressures on the healthcare system. In response, the Thai Ministry of Public Health has launched a comprehensive cancer policy, integrating services across all levels of care from primary health units to tertiary cancer centers to ensure that the increasing number of cancer patients receive timely, comprehensive, and high-quality care (Viryasiri et al., 2024).

Beyond system optimization, staff training, and preventive strategies, facilities also play a crucial role in supporting care delivery across all departments. Well-designed environments enhance staff efficiency, streamline workflows, and improve the overall healthcare experience, contributing significantly to improved patient outcomes and more efficient hospital operations. For instance, optimized layouts enable smoother patient movement between departments, reducing waiting times and enhancing patient satisfaction (Bhatti et al., 2023). Design should support clinical functions by minimizing unnecessary service steps and enabling intuitive navigation. Moreover, the configuration of examination and treatment rooms must allow easy access to equipment and patients, enabling staff to provide timely care. Proper zoning, e.g., the clear separation of high-risk and low-risk areas, enhances operational efficiency and reduces the risk of infection and medical errors (Firoozi & Firoozi, 2025). Supporting infrastructure should also support efficient administrative operations, allowing staff to access essential information (e.g., patient

records and medications) while maintaining data security and privacy standards.

Beyond these general design principles, the design and construction of RODs involve unique complexities due to the specialized nature of cancer care, multidisciplinary collaboration, radiation safety requirements, and extensive supporting infrastructure. First, a patient's journey in an ROD significantly differs from that of other clinical departments. To ensure timely diagnosis and treatment, it must accommodate a continuous flow of cancer patients while minimizing delays in radiation therapy initiation. Second, a wide range of professionals (e.g., radiation oncologists, medical physicists, radiation technologists, nurses, and support staff) work collaboratively to provide comprehensive care (Lam et al., 2015). It requires spatial layouts that facilitate communication, collaboration, and coordinated workflows. Third, the department must be specifically designed for radiation protection due to the presence of high-energy radiation equipment and radioactive materials (Marks et al., 2011). Effective shielding and structural design must comply with national and international safety standards, including those outlined by the Office of Atoms for Peace and the International Atomic Energy Agency (IAEA), to prevent radiation exposure to staff, patients, and the public. Furthermore, RODs must include dedicated spaces for specialized, supporting tasks, e.g., simulation, thermoplastic mask fabrication, and treatment planning (Jellema et al., 2020). These interrelated processes require spatial configurations that support smooth transitions between functions.

To support design of RODs, several guidelines have been proposed, albeit in a fragmented manner across multiple publications, standards, manuals, and handbooks. Many are generalized for broader departments and offer limited specificity for RODs, without integrated framework addressing its unique operational and spatial requirements (Wiriyaikul et al., 2022). Furthermore, relatively few studies incorporate insights from frontline healthcare staff who interact with these spaces daily (Crocker, 2021). Moreover, existing guidelines mostly originate from developed countries such as the United Kingdom (UK), the United States (USA), and Australia, as well as international organizations (Viryasiri et al., 2024). These resources vary in

detail and often emphasize technical specifications (e.g., space allocation ratios and safety standards), reflecting conditions that may not be directly applicable to other socio-economic contexts (Crocker, 2021; Wardhani et al., 2026). There is also limited research addressing ROD design in other settings. In Thailand, for example, the demand for radiation oncology services continues to rise, yet comprehensive, context-specific design guidance is still lacking.

This research therefore aims to (1) amalgamate existing, fragmented ROD design guidelines, (2) explore their implementation challenges, and (3) gather reflections from medical staff. It is expected to help identify existing challenges and inform the refinement of practical, context-appropriate design guidelines for Thailand that support safe, efficient, and patient-centered care.

LITERATURE REVIEW

ROD Resign Criteria

Radiology is a medical specialty that uses imaging technologies to diagnose, manage, and treat diseases (Kantarci et al., 2025). The scope of services varies depending on each hospital's level and service plan. While most RODs focus on diagnostic services, advanced healthcare

facilities may provide both diagnostic and therapeutic services, within a single unit or across specialized departments such as diagnostic radiology, radiotherapy, and nuclear medicine (Mettler Jr et al., 2008). Within the department, the primary users are patients and their families, while the multidisciplinary care team includes radiation oncologists, medical physicists, dosimetrists, radiographers, clinical technologists, nurses, and administrative personnel. Radiotherapy patients differ from typical hospital patients in several respects. Most are treated as outpatients, visiting the department regularly, often multiple times per week, over extended periods or in repeated treatment cycles. These operational characteristics generate specific spatial and functional requirements for departmental design. To address their specialized requirements, this study reviews relevant literature and synthesizes key ROD design criteria (see Table 1).

Radiotherapy services also rely heavily on diagnostic imaging or nuclear medicine to ensure accurate and precise treatment planning. Consequently, ROD facilities house specialized equipment that must be installed according to strict technical and safety standards (Marks et al., 2011). Table 2 presents examples of radiological equipment commonly used to support radiotherapy services.

Table 1
Examples of ROD Design Criteria in Alphabetical Order

Criteria	Description	Reference
1. Accessibility	The ROD should be located near parking to accommodate frequent visits, with convenient access for patients with mobility challenges. Entryways should be at least 1,400 mm wide to allow wheelchair and stretcher access. Waiting areas should include designated seating for disabled users. Proximity to diagnostic radiology should be considered.	(Department of Veterans Affairs [VA], 2008; International Health Facility Guidelines [IHFG], 2017)
2. Cost	ROD design should anticipate technological upgrades, considering demolition costs and choosing reusable materials to reduce long-term expenses.	(Department of Health [DH], 2013)

Table 1 (Continued)

Criteria	Description	Reference
3. Flexibility	The design must accommodate future expansion (e.g., additional simulation or examination rooms) and align with technological advancement. Radiation rooms should include shielding exceeding minimum requirements (e.g., accommodating equipment up to 15 MV). Collaboration among designers, vendors, and physicists is also essential.	(DH, 2013; VA, 2008)
4. Infection control	ROD design must support infection control as immunocompromised and infectious patients may share space. Materials should allow for easy cleaning, handwashing stations must be readily available, and special consideration should be given to airborne diseases (e.g., tuberculosis).	(VA, 2008)
5. Information technology	IT infrastructure should support high-speed data transfer, secure storage, seamless communication, radiation oncology information management, monitoring (e.g., CCTV), and integration with hospital information systems.	(DH, 2013; VA, 2008; IHFG, 2017)
6. Laws and regulations	Due to the use of high-energy radiation and radioactive materials, ROD designs must comply with regulations on radiation safety, environmental monitoring (e.g., water contamination), and waste disposal to minimize risks.	(DH, 2013)
7. Privacy	Patient privacy must be prioritized through secure data handling and spatial design supporting confidentiality. Acoustic measures should be implemented in consultation, examination, and office areas to ensure privacy during patient-provider communication.	(IHFG, 2017)
8. Satisfaction and well-being	The environment should minimize stressors (e.g., noise, poor lighting, and lack of privacy) and maintain comfortable indoor conditions (e.g., temperature, ventilation, and acoustics). Design should reflect cultural familiarity and patient expectations, while providing family accommodation and ergonomic workspaces for staff.	(VA, 2008; Jiravanichkul et al., 2026)
9. Safety	ROD spaces must support equipment structural load and ceiling-mounted devices, with a minimum ceiling height of 3 meters. Radiation rooms require adequate shielding and maze entrances, verified by certified physicists. Additional measures include CCTV, nurse call systems, fall-prevention design, and seismic considerations where relevant. Expert consultation is required for radioactive decontamination or equipment replacement.	(VA, 2008; IHFG, 2017)
10. Space utilization	The design must support inpatient and outpatient workflows, integrating simulation, treatment planning, and follow-up exams. Proximity to diagnostic radiology and, where applicable, shared spaces with nuclear medicine should be considered. At least two treatment rooms are recommended, and pediatric-friendly areas may reduce anxiety and increase cooperation among children.	(DH, 2013; VA, 2008; IHFG, 2017)
11. Sustainability	ROD designs should adopt life cycle principles to enhance energy efficiency, water conservation, and indoor environmental quality, ultimately reducing facility operating costs and promoting health and productivity.	(VA, 2008)

Table 2*Examples of Specialized ROD Equipment*

Radiology Machine	Usability
1. CT-Simulator	A computed tomography (CT) system used to create three-dimensional images for accurate treatment planning and simulation in radiotherapy.
2. MRI-Simulator	A magnetic resonance imaging (MRI) system used to simulate treatment by providing high-resolution soft tissue contrast, enhancing the precision of target delineation.
3. Medical Linear Accelerator Base	A machine that generates high-energy photon (X-ray) and electron beams for delivering external beam radiation therapy to cancerous tissues with precision.

The design of RODs is therefore inherently complex and highly specialized, shaped by the unique characteristics of radiotherapy patients, the multidisciplinary nature of care teams, and the integration of advanced medical technologies. Unlike other departments, it must accommodate frequent outpatient visits, coordinate diagnostic and therapeutic functions and comply with stringent safety and regulatory standards. The built-environment must support patient-centered care while accommodating evolving clinical workflows and future technological advancements.

ROD Design Guidelines

To support the implementation of the complex and highly specific design criteria outlined in the previous section, several international organizations have developed formal guidelines to assist designers. A comparative synthesis of major ROD design guidelines across the US, UK, Australia, Thailand, and international organizations is summarized in Appendix A, focusing on spatial programming, patient and staff accommodation, accessibility, and equipment-specific requirements.

Across these standards, common priorities include radiation safety, patient accessibility, and efficient clinical workflows. International frameworks developed by the IAEA and WHO, for example, provide broad recommendations addressing radiation shielding, operational functionality, and safety systems (e.g., warning lights, CCTV monitoring, and emergency stop

mechanisms) to ensure safe treatment delivery (International Atomic Energy Agency [IAEA] & World Health Organization [WHO], 2021). Similarly, UK and US guidelines prioritize patient-centered clinical workflows, recommending spatial arrangements that support privacy, accessibility for wheelchair and stretcher users, and effective patient observation from control rooms (DH, 2013; Rostenberg & Horii, 2006; VA, 2008). These guidelines primarily focus on clinical functionality and patient safety, often presenting qualitative planning principles rather than strict numerical spatial standards.

In contrast, Australian guidelines provide some of the most detailed and prescriptive spatial requirements among the reviewed standards (IHFG, 2017). They specify minimum room sizes, functional allocations, and staff-related spatial provisions across most departmental areas, including consultation rooms, treatment planning areas, physics laboratories, and staff facilities. This quantitative approach supports standardized facility planning and operational efficiency but may reduce flexibility when applied to different healthcare contexts.

Thai guidelines, by comparison, define spatial requirements primarily through area calculations based on occupancy or equipment needs, such as minimum area per seat, sanitary fixture, or treatment function, while providing fewer recommendations on spatial hierarchy, patient experience, or workflow optimization (Ministry of Public Health [MOPH], 2021). This initial review highlights inconsistencies in scope among guidelines, fragmentation across multiple documents, and variations in contextual

assumptions, which suggest the need for systematic analysis and contextual adaptation in specific healthcare settings.

Situations in Thailand

Hospital design practices in Thailand have evolved within a complex healthcare landscape shaped by rapid service demand growth, incremental infrastructure expansion, and uneven resource distribution (Viryasiri et al., 2024). Public hospitals have undergone decades of piecemeal development to accommodate increasing patient volumes, limited hospital capacity, and rising healthcare utilization, resulting in fragmented spatial configurations and limited adaptability (Prugsiganont & Jensen, 2019; Waroonkun & Prugsiganont, 2022). Consequently, Thai hospitals face persistent challenges in accessibility, wayfinding, spatial flexibility, and functional integration (Viryasiri et al., 2024). Research also shows that nonclinical and diagnostic areas frequently exhibit poor spatial orientation, inefficient patient flow, and ad hoc modifications that hinder holistic planning and operational coherence.

Research further highlights systemic limitations affecting specialized departmental planning. Although Thai designers recognize global design principles such as healing environments, flexibility, sustainability, and patient-centeredness, their application is often constrained by regulatory frameworks, budget limitations, aging infrastructure, and contextual misalignment with imported design standards (Mannontaratana et al., 2025). Many principles developed in high-income countries therefore require adaptation or, in some cases, rejection due to differences in clinical workflows, cultural norms, land availability, and maintenance capacities in Thai public hospitals (Viryasiri et al., 2024). The fragmentation of roles among architects, engineers, and operators, together with limited interdisciplinary coordination, perpetuates design inefficiencies across the facility lifecycle and hinders opportunities for long-term strategic planning (Laovisutthichai et al., 2025).

Moreover, Thailand's medical technology ecosystem influences hospital spatial planning. The country relies heavily on imported high-tech

equipment, while domestic production tends to focus on low-value, less-complex devices, limiting opportunities for integrated development between medical technology and spatial design (Ariyatum et al., 2009). As a result, hospitals often retrofit existing spaces to accommodate new technologies rather than designing integrated environments for future technological evolution. Collectively, these conditions reveal that although Thailand has made substantial progress in healthcare provision, its physical infrastructure, particularly in technologically intensive departments, has not fully kept pace with clinical and technological advancement. It underscores the need for detailed investigation into spatial organization, workflows, and design requirements of RODs, which involve even greater technical and operational complexity than general hospital areas.

METHODOLOGY

This research adopted a pragmatist epistemological position. Pragmatism, in a nutshell, prioritizes practical consequences and utility, thereby advocating for the adoption of methodologies demonstrating efficacy in confronting real-world challenges (Allmark & Machaczek, 2018). Given the multifaceted nature of ROD design, a mixed-methods approach was employed, combining both qualitative and quantitative methods to enhance the validity and comprehensiveness of the findings (Ostlund et al., 2011). In this research, this approach provided a holistic understanding of existing conditions, user needs, and optimal design considerations. The study unfolded across four key phases: (1) gathering existing requirements through a comprehensive literature review, (2) analyzing real-world construction drawings in depth, (3) conducting extensive site visits for empirical observation, and (4) performing follow-up interviews.

Literature Review

A literature review was conducted to consolidate design criteria and space requirements for RODs. Searches were performed in Google Scholar, Scopus, and Web of Science, using keywords

such as “radiation oncology department,” “radiology department design,” and “radiology equipment requirements.” Collected publications were then screened using two criteria: (1) composition in English or Thai, and (2) provision of specific ROD design criteria and space requirements. Relevant sources were synthesized from:

- Design guidelines issued by healthcare organizations focusing on the ROD’s facility, patient flow, and staff ergonomics;
- Academic research on healthcare architecture and the ROD’s design; and
- Laws and regulations governing medical environments, particularly radiation safety.

Extracted data were consolidated into comprehensive ROD design criteria, e.g., cost, privacy, infection control, and equipment specifications (see Table 1), as well as space requirements (see Appendix A). These tables informed subsequent empirical analysis and provide a reference for ROD design practice.

Construction Drawings Analysis

To understand existing design practices for RODs in Thailand, a detailed analysis of construction drawings was undertaken, focusing on spatial organization, functional zoning, and inter-spatial relationships within the selected cases. The case studies were selected based on the following criteria: (1) the institution’s operational scale and role as major radiotherapy service providers, (2) institutional characteristics as tertiary-care public hospitals with comparable technology and service levels, and (3) accessibility of construction documentation for detailed spatial analysis. Construction drawings from three cases were gathered (see Table 3). Although the cases were completed in different periods, this allows examination of how facilities have adapted to evolving technologies, practices, and guidelines over time.

These architectural drawings were analyzed following a systematic methodology comprising:

- Zoning analysis: examination of the spatial organization of functional areas (e.g.,

waiting, consultation, treatment, staff areas, and machine bunkers);

- Functionality assessment: evaluation of intended uses and operational flows to assess functional adequacy;
- Relationship mapping: analysis of proximity and connectivity between spaces to assess patient and staff circulation efficiency; and
- Guidelines comparison: comparison of layouts against space requirements and design criteria derived from the literature review.

This comparative analysis identified discrepancies between current designs and established guidelines, assessed adherence to recommended practices, and highlighted potential areas for improvement.

Site Visits

Complementing the architectural drawing analysis, site visits were conducted at all cases to facilitate direct, empirical investigation of the physical environment and the lived experience within the ROD. The visits included:

- Walk-through observations: systematic assessment of (1) physical conditions (e.g., current state, maintenance, and overall ambiance), (2) spatial dimensions and configuration, (3) spatial utilization, and (4) workflow patterns to identify efficiencies and bottlenecks;
- Informal discussions: engagement with key personnel (e.g., department heads, nurses, and technicians) to provide contextual understanding of daily operations, challenges, and functional requirements, and to validate observations; and
- Documentation: collection of field notes, photographs, and sketches to record spatial conditions and key issues.

The collected data, including physical conditions, space utilization, and observed workflows, were systematically analyzed and triangulated with findings from the literature review and construction drawings to identify discrepancies between design intent and actual use, validate observations, and assess the functional performance of the built environment.

Table 3*Case Studies*

Case	A	B	C
Layout			
Explanation	Case A originated as a three-floor extension of a single-story building, integrating a chemotherapy room and a radiation machine to support early cancer treatment approaches.	Case B underwent subsequent extensions to accommodate additional radiation machines and simulators, housing six radiation machines.	Case C dedicates its basement floor to the ROD, with three new radiation machines installed to address increasing patient load and service demand.
Construction/expansion year	1965 (Construction) 1981 (Expansion)	1985 (Construction) 2004 (Expansion)	2016 (Construction)
Floor area	1,427.30 sqm	1,943.02 sqm	1,096.53 sqm
Primary function	Radiation Simulation Therapy Services	Radiation Simulation Therapy Services Outpatient Department	Radiation Simulation Therapy Services Outpatient Department*
Installed equipment	Linear Accelerator RapidArc CT-Simulator Acuity Simulator	Linear Accelerator RapidArc CT-Simulator MRI Simulator	Linear Accelerator (including True beam, Halcyon, Ethos) CT-Simulator MRI Simulator Brachytherapy

Note. *Future expansion

Follow-up Interviews

To obtain staff perspectives on operational and spatial challenges, follow-up interviews were conducted. Participants were selected using a targeted exponential non-discriminative snowball sampling approach, beginning with a key informant, the head of the department, who recommended additional participants within the department. This approach enabled the identification of highly relevant professionals. The sample group comprised personnel with at least five years of experience in the ROD and

involvement in one of the three cases. These criteria ensured that participants possessed a comprehensive understanding of the departmental evolution, current operational challenges, and long-term needs. The interviewees included 3 radiation oncologists, 6 medical physicists, 5 radiation technicians, and 5 nurses. Semi-structured interview protocols were developed to explore the following themes:

- Functional adequacy: The effectiveness of current spaces in supporting daily tasks and responsibilities.

- Spatial limitations: Challenges related to space constraints, layout issues, or inadequate facilities.
- Workflow efficiency: Perceptions regarding bottlenecks, inefficiencies, and areas where spatial design hinders optimal workflow.
- Environmental quality: Views on lighting, acoustics, privacy, comfort, and their impact on patient and staff well-being.
- Unmet needs: Crucial missing elements or desired improvements within the physical environment.
- Differences from international standards: Perspectives on whether local context necessitates varied design considerations compared to international guidelines.

The qualitative data obtained from the interviews were transcribed and analyzed using thematic analysis to identify recurring patterns, key challenges, and emerging needs. Interview findings were then systematically compared and triangulated with evidence from the literature review, construction drawings, and site visits. This triangulation helped validate findings, identify operational challenges, and contextualize spatial issues within real-world practice. Grounded in pragmatism, this multi-faceted

approach provided a practical understanding of the research problem, leading to evidence-based recommendations for improving ROD facility design.

Notably, this research received ethical approval from the Institutional Review Board (IRB) of both the university and the participating hospital. Participants were provided with sufficient information about the study to make informed decisions free from coercion, pressure, or undue inducement. Participants' rights, including the right to withdraw at any stage, were fully respected. No personal or patient data were collected. All collected data were anonymized, securely stored, and used solely for research purposes.

RESULTS

This section presents a comprehensive analysis of three cases, focusing on architectural layout, spatial configurations, and functional performance, based on construction drawings, site observations, and in-depth interviews (see Table 4).

Table 4
Results

Case	A	B	C
Zoning	1st Floor 	1st Floor 	B1st Floor 
	2nd Floor 		

Table 4 (Continued)

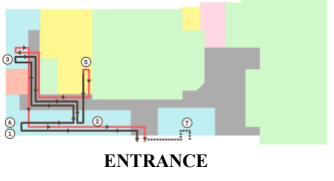
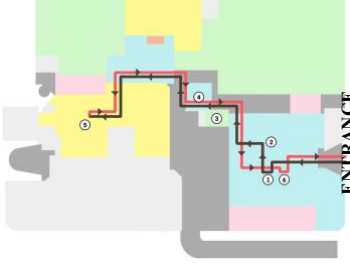
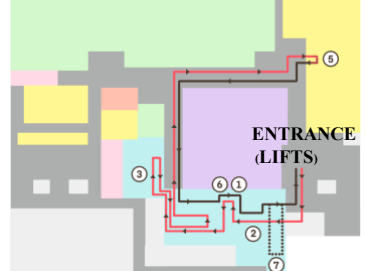
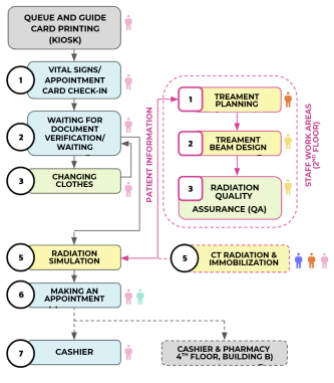
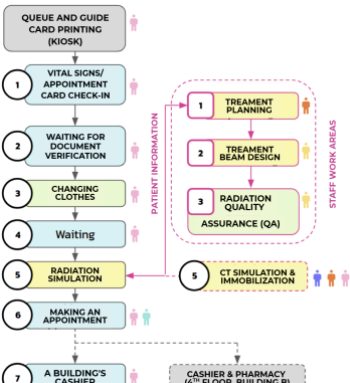
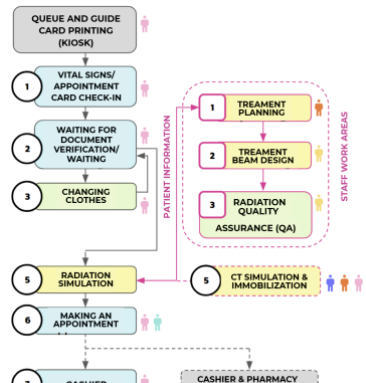
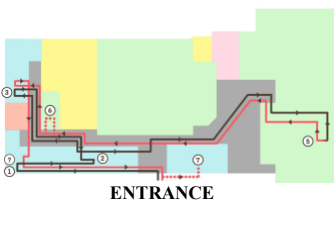
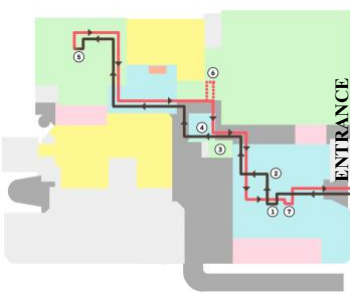
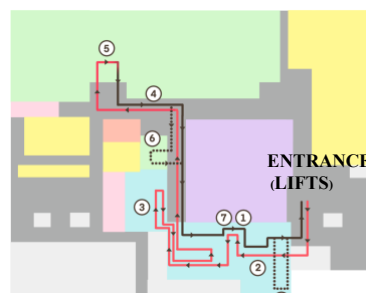
Case	A	B	C
Function & Size	TREATMENT DELIVERY 56.28% TREATMENT PLANNING AND EQUIPMENT PREPARATION 20.49% (FL1 - 9.93% FL2 - 10.55%) WAITING AREA 14.92% STAFF OFFICE 6.92% (FL1 - 2.73% FL2 - 4.19%) CONSULTATION AND EXAMINATION 1.40%	TREATMENT DELIVERY 43.84% WAITING AREA 27.03% TREATMENT PLANNING AND EQUIPMENT PREPARATION 22.20% STAFF OFFICE 6.93%	TREATMENT DELIVERY 46.22% TREATMENT PLANNING AND EQUIPMENT PREPARATION 27.35% WAITING AREA 21.13% STAFF OFFICE 3.89% CONSULTATION AND EXAMINATION 1.42%
Flow	RADIATION SIMULATION 	RADIATION SIMULATION 	RADIATION SIMULATION 
			
	IRRADIATION 	IRRADIATION 	IRRADIATION 

Table 4 (Continued)

Case	A	B	C
Depth level			
Adjacency			
Remark:	RADIATION ONCOLOGISTS NURSES WAITING AREA TREATMENT DELIVERY STAFF OFFICE IN MEDICAL PHYSICISTS PATIENTS CONSULTATION AND EXAMINATION BRACHYTHERAPY NON-STUDY AREAS OUT RADIOGRAPHERS TREATMENT PLANNING AND EQUIPMENT PREPARATION RECEPTION AND WAITING AREA PATIENT CONSULT AREA TREATMENT PLANNING AND APPLIANCE AREA RADIATION THERAPY TREATMENT AREA BRACHYTHERAPY AREA STAFF AREA HALLWAY		

Zoning

Waiting Area

In Cases A and C, the waiting areas are located adjacent to the main entrance and consolidated into a single shared space, facilitating convenient access. However, both observations and staff interviews indicated limited privacy, as patients who had already changed into treatment gowns were required to wait in the same area as other patients and accompanying relatives. In contrast, Case B divides waiting areas into three zones aligned with treatment stages: (1) initial contact and general waiting for first-time patients, (2) consultation waiting for outpatient services, and (3) simulation and radiation treatment waiting. Though this zoning approach reflects functional separation, interview participants noted that the resulting spatial layout can be fragmented and confusing, requiring additional staffing to manage patient flow. To enhance patient experience and operational efficiency, waiting areas should therefore incorporate clear circulation, sequential spatial organization, and visual cues (e.g., signage and interior differentiation) to support privacy and navigation.

Consultation and Examination

Only Case B provides a dedicated consultation and examination zone, yet it overlaps spatially with the general waiting area. Observations and interviews revealed that physicians often conduct patient interviews within these shared zones, compromising confidentiality due to the absence of acoustically secure consultation rooms. Interview participants also confirmed that sensitive discussions frequently occur in semi-public areas, highlighting the lack of private consultation spaces. To address these issues, consultation and examination areas should be enclosed, purpose-built rooms located away from high-traffic zones. These rooms must offer both visual and acoustic privacy, accommodate wheelchair and stretcher access, and be equipped with appropriate medical and diagnostic facilities.

Treatment Planning and Equipment Preparation

In Cases A and C, treatment planning areas share space with public waiting zones, resulting in limited privacy. In Case A, staff interviews revealed functional challenges, including calibration and physics equipment rooms located within staff break areas, where clutter obstructs equipment access and movement. Moreover, its CT simulation room opens directly into the public waiting area, without visual screening, exposing sensitive treatment zones. In Case C, an improvised row of chairs outside the CT-simulation room serves as a temporary waiting area for patients awaiting procedures. Conversely, Case B provides a dedicated waiting area for simulation and radiation treatment phases, helping to reduce congestion. Nonetheless, even in Case B, spatial arrangements of the waiting lounge, changing rooms, and treatment planning rooms still lack adequate privacy. To enhance privacy, efficiency, and operational safety, future treatment planning and equipment preparation areas should therefore be clearly separated from public waiting zones, incorporate visual privacy controls, and include adequately sized support spaces.

Treatment Delivery

In Cases A and C, treatment delivery waiting areas are shared with general waiting areas, whereas in Case B, they overlap with the treatment planning zone. Across all three cases, staff noted that patients wearing treatment gowns frequently wait in public zones, compromising dignity and privacy. In Case C, the treatment room is in a more secluded zone, offering inherent privacy. However, the absence of a dedicated internal waiting area led staff to create a temporary waiting space outside the control room, where patients have direct sightlines to treatment control screens through CCTV displays, further compromising the privacy of those undergoing radiation therapy.

Staff Office

According to international guidelines, medical physicists' offices should be located near simulation rooms within quiet, controlled

environments. In Cases A and C, staff and patient zones are clearly separated. Case A places patient functions on the first floor and staff zones on the second, while Case C utilizes separate pathways and areas for staff and patients, allowing professional communications without patient exposure. However, interviews indicated a lack of security systems, such as key card access, posing risks of unauthorized patient entry into staff areas. In contrast, Case B lacks separation between staff and public areas. The physicists' workroom is in a high-traffic area with insufficient acoustic privacy, disrupting concentration required for precision-driven tasks. Staff office design should thus prioritize acoustically isolated, access-controlled staff workspaces to ensure security, concentration, and interdisciplinary collaboration.

Size

Waiting Area

Architectural drawings show that Case A allocates a relatively small main waiting hall, resulting in tightly packed seating that restricts maneuverability especially for elderly patients with walking aids. In contrast, Cases B and C appear to have more spacious waiting areas due to integration with outpatient consultation seating and brachytherapy zones, respectively. However, staff interviews indicated that Case B experiences high congestion in the afternoon, as it serves regular-hours, after-hours, and overflow patients. Case C accommodates only simulation and treatment services, making the space adequate. Notably, its planned expansion to include outpatient consultation is expected to increase congestion.

Across all cases, waiting areas lack functional flexibility, deviating from guideline recommendations. There are insufficient dedicated parking areas for wheelchairs and stretchers. Although Case C provides a 3.70-meter-wide circulation zone, allowing wheelchairs to be parked without obstructing movement, it may become insufficient once future expansion occurs. Further functional deficits include the lack of accessible toilets for stretchers or wheelchair-bound patients in all cases. In Case B, restroom entrances are also narrow and difficult to access,

exacerbating usability issues. Future waiting areas should provide sufficient, flexible space with dedicated zones for wheelchair and stretcher users, scalable capacity for peak congestion, and accessible facilities, depending on functions and services provided.

Consultation and Examination

Currently, only Case B provides operational consultation services, while Case C plans to offer such services in the future. Neither Case B nor the proposed Case C design includes dedicated, private history-taking or consultation rooms. Staff interviews revealed that patients in wheelchairs or on stretchers must be consulted in open waiting areas due to narrow examination room doors and limited room size. These constraints reduce patient privacy and limit the involvement of accompanying family members in physician discussions. The overall waiting capacity is inadequate, and no space is reserved for assistive devices in circulation zones. Although the number of available examination beds is insufficient relative to the number of attending physicians, this shortfall somehow appears to stem from workforce planning rather than architectural programming.

Treatment Planning and Equipment Preparation

Staff reported that Case A contains only a CT simulator, whereas current clinical protocols often require both CTs and MRIs for comprehensive treatment planning. As a result, patients must undergo MRIs at a separate facility, adding logistical inefficiencies. In Case B, the conventional simulator is rarely used due to advancements in technology. It is occasionally repurposed as an auxiliary recovery space when standard beds are full. In Case C, the CT simulation unit is installed in a configuration where the operator cannot view the patient from the foot end via the control room window. This deviation necessitates the use of CCTV for indirect monitoring. Although technically acceptable, physicians expressed discomfort with this indirect viewing method.

Treatment Delivery

Across all cases, the limited size of treatment areas fails to provide privacy-enhancing zones, as recommended by design guidelines. In Case A, nine treatment rooms vary in size. Older rooms were originally designed for smaller machines and now lack adequate vertical clearance for modern equipment, with some units nearly touching the ceiling. Furthermore, CCTV placements create blind spots that could endanger staff or patients. In Case B, two treatment rooms share a single corridor, whose width is inadequate for simultaneous stretcher movement. Additionally, the winding layout of the corridor complicates patient calling and movement. Patient toilets are located too far from treatment rooms, often leading staff to allow patients to use staff restrooms. While architectural drawings of Case C indicate separate waiting areas for gowned and non-gowned patients, field observations show that all patients are instructed to change into treatment gowns upon arrival, rendering the separation functionally obsolete.

Control rooms in Cases A and B are smaller than recommended standards, with cramped access routes requiring staff to sidestep when passing. Recovery rooms are undersized, unable to accommodate peak patient volumes. Radiation safety concerns were also identified: In Case A, primary beam rotation intersects adjacent treatment room corridors, while in Case B, beam paths intersect control rooms, a non-compliant radiation shielding layout. Additionally, the suction system in Case B's built-in exhaust ducts was reportedly underpowered, requiring mobile units.

Notably, none of the buildings include dedicated mask-making or immobilization equipment storage rooms. Staff store equipment inside treatment rooms for convenience, though this practice raises contamination risks. Storage cabinets within treatment rooms were also found to be undersized, with inadequate width and depth for proper organization. To accommodate technological advancements and evolving care models, future treatment areas should be large, flexible, and designed to allow privacy, safety, and adaptability.

Staff Office

Staff lounges in all three buildings are small and inadequate for dining or rest. In Case B, although staff noted that the office could facilitate communication, it was found to be cramped. Importantly, staff and patients share restrooms due to the absence of patient toilets near treatment zones, posing further operational challenges and violating best practice in spatial separation.

Circulation

Architectural layouts in Cases A and B reveal a shared circulation path for inpatients, outpatients, and medical staff, with no separation between public and service pathways. However, operational outcomes differ significantly due to variations in building size and spatial configuration. In Case A, the compact layout creates short, direct routes, reducing complexity and preventing cross-circulation. Patient movement is straightforward, and key facilities such as restrooms are easily accessible. Nonetheless, equipment transport paths intersect staff dining areas, disrupting workflow, and narrow corridors limit access to nursing stations and storage rooms.

In contrast, Case B, a larger facility with more services, retains a unified circulation path, producing complex spatial flow as patients pass through multiple waiting areas. Multiple entrances further cause disorientation. Equipment transportation paths are lengthy and inefficient, and corridors outside treatment rooms are narrow. A recurring problem in both cases is that shared circulation routes compromise privacy in the CT control room, where patient trolleys pass directly in front of the control area, resulting in frequent visual and spatial intrusion.

Case C adopts separate circulation routes for patients and staff, including a staff-only elevator connected directly to secure work areas. An equipment transport path is efficiently located adjacent to the radiotherapy zone, improving logistics and safety. However, the patient route in Building C—though not objectively long—feels comparatively distant when evaluated against the compact design of Building A. Additionally, some risk of cross-circulation with other functional

zones may occur, compromising spatial clarity. It can be inferred that while shared circulation routes may be appropriate in compact facilities with limited services, larger facilities with higher traffic volumes benefit significantly from dedicated circulation systems that support operational autonomy, patient dignity, and streamlined logistics.

Spatial Depth and Hierarchy

Analysis of spatial configurations reveals that Case A's compact, single-story layout lacks depth-level zoning, with all functions located on the ground floor and without any intermediate sub-waiting or transition zones before entering the radiotherapy suite. This absence of spatial hierarchy reduces privacy and safety control.

Case B—although also single-story—accommodates multiple functional units, including outpatient consultation, treatment planning, and radiotherapy. While its layout introduces some degree of spatial depth, it lacks clarity and coherence. Functional areas exist at different depth levels without clear sequencing, leading to confusing navigation and fragmented zoning.

Case C, a newly constructed facility, demonstrates a clearer spatial hierarchy, though its service functions mirror those of Case B. The zoning progression is clear but not excessive, facilitating both user navigation and effective operational control. Field validation confirmed the architectural intent and the practical benefits of this structured depth arrangement. Hence, future ROD designs should have a clear depth hierarchy, organizing public, semi-public, and restricted zones in a logical sequence, to improve privacy, safety, and wayfinding without overcomplicating the layout. It should also ensure the spaces are straightforward and easy to locate.

Adjacency

From a patient-centered perspective, consultation rooms, simulation suites, and treatment rooms should be located adjacent to one another to minimize patient movement and streamline procedural flow. This practice is

generally observed in all three cases, where these functions are collocated, overlapping, or shared. According to the standard, changing rooms should be positioned near simulation suites. However, local adaptations are necessary. For example, in Case C, the changing area is shared between the CT simulation and radiotherapy treatment rooms—a reflection of Thailand's high-volume, fast-paced service context. Although this compromises the ideal zoning separation, it remains aligned with operational needs.

Operational challenges also arise from dispersion of interdependent functions. In terms of staff workflow, equipment storage rooms should be adjacent to treatment rooms. While Case A meets this criterion on plan, actual use reveals that the storage room is located deep within the staff area, requiring personnel to walk through non-clinical zones to retrieve equipment. Case B disperses its treatment rooms across two zones, unavoidably distancing some rooms from the central storage area.

All cases lack dedicated mask fabrication rooms. Instead, mask-making equipment is installed inside CT simulation rooms, despite the heat and humidity generated during the process. In Case B, a heat-based mask-forming machine is placed in the CT room, and a water-boiling system is installed inside the MRI room, which require additional drying space on the second floor. These boiling systems were used for their reusability and cost-effectiveness. Although staff reported that integrating mask fabrication within simulation rooms improves workflow efficiency by reducing transport time, this approach compromises environmental control and increases contamination risks. A separate mask fabrication room located between the MRI and CT rooms would be preferable, as both modalities are routinely used in the mask preparation process. Staff interviews also noted the importance of proximity to patient beds, suggesting that immediate accessibility takes precedence in daily operations.

Ideally, physicists' and physicians' workspaces should be collocated to facilitate seamless interdisciplinary collaboration. However, in all cases, their separation has resulted in workflow inefficiencies, as staff are frequently required to travel between areas. The system also lacks a consistent protocol for assigning physicists to

specific places, which exacerbates coordination delays and communication breakdowns. Case A additionally places a meeting room above the radiotherapy suite, where radiation shielding may be insufficient for prolonged occupancy, highlighting the need for re-evaluation of radiation safety compliance.

Overall, patient areas should be clustered to ensure intuitive flow, while staff zones should be collocated to support efficient collaboration, each supported by dedicated facilities such as restrooms and changing rooms.

DISCUSSION

The above results identify key challenges in the design and operation of RODs in Thailand, where contextual conditions and architectural practices differ from established international standards and guidelines.

- Overcrowding in waiting areas during peak hours was a recurring issue, driven by high patient volume and cultural factors. Many patients, particularly those from other provinces, arrive early, while accompanying relatives further increase congestion.
- Facilities were not designed for such volumes or user needs, especially wheelchair and stretcher access. Circulation widths, restroom access, and consultation room sizes often fail to accommodate elderly or mobility-impaired patients.
- Waiting areas are enclosed with limited daylight and privacy, especially for patients in gowns waiting in public zones. This contrasts with international guidelines, where patients proceed directly from changing rooms to simulation or treatment areas.
- Consultation rooms are insufficient. Spatial layouts do not align with clinical workflows or international standards, due to limited resources, lack of anticipatory planning, and the need to serve higher patient volumes than typically found in Western contexts.

These findings reflect both physical constraints and a mismatch between theoretical design principles and human-centered local needs. While some international ROD design guidelines remain applicable (e.g., wheelchair and stretcher accessibility), their detailed application requires

contextual adaptation due to differences in patient volume, workflow patterns, and equipment management. They highlight the value of co-design, as recurring issues could have been mitigated through early stakeholder involvement, ensuring that technically driven ROD planning aligns with operational realities and user needs. Moreover, they underscore the importance of introducing localized design guidelines at the earliest stage. In this regard, this study identifies several key design considerations for Thailand.

- Zoning should separate waiting areas by treatment stages, while maintaining sequential adjacency supported by clear circulation and signage.
- Space sizing should be addressed through integrated operational, technological, and architectural planning from the outset. Larger and more flexible spaces are required to accommodate technological change, high patient volumes, limited patient mobility, and accompanying relatives.
- Circulation should clearly separate patient and staff movement, remain simple and direct, and align with local clinical workflows.
- Spatial depth hierarchy should organize the department into: Level 0 (public waiting and registration), Level 1 (semi-public waiting near simulation and treatment zones), Level 2 (controlled treatment and simulation rooms restricted to patients and staff), and Level 3 (staff-only areas accessed via controlled connections). This hierarchy encourages a shift from technology-centered planning toward human-centered spatial organization prioritizing privacy, safety, and navigational clarity.
- Functional adjacency should prioritize proximity among consultation rooms, simulation suites, and treatment rooms to reduce patient movement. Physician and physicist workspaces should also be collocated to support collaboration.

This research offers both theoretical and practical contributions.

- For scholars, it highlights the contextual limitations of applying international guidelines in different settings, supporting the development of localized, context-sensitive design frameworks in

which flexibility and human-centered design are key pillars of future ROD development.

- For practitioners, it provides preliminary spatial and operational strategies tailored to the Thai context, serving as a reference for future ROD design and planning.
- At the policy level, the findings also support authorities in developing design guidelines and standard drawings for ROD facilities in Thailand.

However, several limitations should be acknowledged. First, this study is based on three case studies in Thailand. Its findings should be interpreted cautiously when applied to healthcare systems with different sociocultural, institutional, and service contexts. Second, the proposed design and spatial management guidelines remain preliminary. Further validation is required through additional case studies, quantitative spatial analysis, and broader qualitative inquiry. Finally, ethical constraints restricted access to certain in-depth information. As a result, this study primarily reflects staff perspectives rather than patient experiences, since direct patient engagement was limited to avoid disturbing individuals undergoing sensitive treatment processes.

CONCLUSION

As RODs evolve alongside patients' changing conditions, this research reveals shifting spatial needs across the continuum of care, from initial contact, consultation, and gown changing to simulation, treatment, and staff support. Each space demands distinct spatial functions shaped by contextual conditions, while all spaces must remain seamlessly connected to support diverse user flows and intuitive navigation. To address these challenges, the study provides preliminary design guidance tailored to RODs in Thailand. Key recommendations include: 1) allocating larger and more flexible spaces than typical departments to accommodate new equipment, high patient volumes, limited mobility, and wheelchair or stretcher access; 2) ensuring adequate space for equipment storage and radiotherapy-specific quality assurance; 3) implementing clear zoning that separates waiting areas by treatment stage while maintaining

sequential adjacency, supported by intuitive circulation and signage; 4) establishing a spatial depth hierarchy; and 5) ensuring functional adjacency among patient areas and staff zones to enhance workflow efficiency and communication.

ROD design is critical due to the department's complex and specialized operations, which has led to the development of numerous international guidelines. This research supports it by synthesizing existing standards, identifying their implementation challenges, and incorporating staff perspectives to propose preliminary, context-sensitive design recommendations. Specifically, it contributes a practical framework for planning and managing ROD spaces within the Thai healthcare context. To further strengthen and validate this guidance, future research is recommended to 1) include more case studies to enhance generalizability, 2) apply a post-occupancy evaluation tailored to RODs, 3) investigate patient experiences more deeply, particularly how spatial configurations affect psychological comfort, dignity, and accessibility during radiotherapy, and 4) develop integrated design-operation models that link architectural planning with ROD workflows.

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REFERENCES

- Allmark, P., & Machaczek, K. (2018). Realism and pragmatism in a mixed methods study. *Journal of Advanced Nursing*, 74(6), 1301–1309. <https://doi.org/10.1111/jan.13523>
- Ariyatun, B., Holland, R., Sirisalee, P., & Prommin, D. (2009). Identifying strategic directions for design development of general hospital equipment for Thailand. *The Design Journal*, 12(1), 69–93. <https://doi.org/10.2752/175630609X391578>
- Bhatti, O. S., Ghufuran, M. A., & Shah, A. U. (2023). Transforming adversity into opportunity: Assessing user satisfaction in hospital transformation in lieu of a pandemic through the multi-corridor expansion model for epidemic management and environmental design enhancement. *Nakhara: Journal of Environmental Design and Planning*, 22(2), Article 308. <https://doi.org/10.54028/NJ202322308>
- Crocker, S. (2021). A call for intersectional healthcare design research. *HERD: Health Environments Research & Design Journal*, 14(1), 273–277. <https://doi.org/10.1177/1937586720964729>
- Department of Health. (2013). *Health building note 02-01: Cancer treatment facilities*. https://www.england.nhs.uk/wp-content/uploads/2021/05/HBN_02-01_Final.pdf
- Department of Veterans Affairs. (2008). *Radiation therapy service design guide*. <https://www.cfm.va.gov/til/dGuide/dgRadTh.pdf>
- Firoozi, A. A., & Firoozi, A. A. (2025). *Transformative design in healthcare*. Springer Nature Switzerland.
- International Atomic Energy Agency. (2008). *Setting up a radiotherapy programme: Clinical, medical physicals, radiation protection and safety aspects*. https://www-pub.iaea.org/MTCD/Publications/PDF/pub1296_web.pdf
- International Atomic Energy Agency. (2014). *Radiotherapy facilities: Master planning and concept design considerations*. <https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1645web-46536742.pdf>
- International Health Facility Guidelines. (2017). *Part B – health facility briefing & design: 230 oncology unit – Radiation*. https://www.healthfacilityguidelines.com/ViewPDF/ViewIndexPDF/IHFG_part_b_oncology_radiation
- International Atomic Energy Agency, & World Health Organization. (2021). *Technical specifications of radiotherapy equipment for cancer treatment*. <https://www.who.int/publications/i/item/9789240019980>
- Jellema, P., Annemans, M., & Heylighen, A. (2020). The roles of cancer care facilities in users' well-being. *Building Research & Information*, 48(3), 254–268. <https://doi.org/10.1080/09613218.2019.1620094>
- Jiravanichkul, S., Pinich, S., Sreshthaputra, A., & Jarutach, T. (2026). Does one size fit all? Well-being environmental assessment criteria in low- and middle-income aging communities in Thailand. *Nakhara: Journal of Environmental Design and Planning*, 25(1), Article 604. <https://doi.org/10.54028/NJ202625604>
- Kantarci, M., Aydin, S., Oğul, H., & Kizilgöz, V. (2025). New imaging techniques and trends in radiology. *Diagnostic and Interventional Radiology*, 31(5), 505–517. <https://doi.org/10.4274/dir.2024.242926>
- Laovisutthichai, V., Viryasiri, T., Low, S. P., Sangnin, K., Kramomtong, W., & Panjapiyakul, N. (2025). Collaborative architecture, engineering, construction, and operations (AECO) practice model for healthcare facilities in Thailand. *International Journal of Construction Management*, 1–21. <https://doi.org/10.1080/15623599.2025.2546014>

- Lam, J., Ng, B., Shen, S., & Wong, C. (2015). How is interprofessional collaboration applied by radiation therapists in the radiation therapy department in British Columbia? *Journal of Medical Imaging and Radiation Sciences*, 46(3), S43–S51.
<https://doi.org/10.1016/j.jmir.2015.04.016>
- Mannontaratana, P., Laovisutthichai, V., Viryasiri, T., Jamnothai, M., & Poonpermpun, W. (2025). Prescriptive-based building regulations: Challenges and recommendations for modernization in the case of Bangkok. *Nakhara: Journal of Environmental Design and Planning*, 24(3), Article 519.
<https://doi.org/10.54028/NJ202524519>
- Marks, L. B., Jackson, M., Xie, L., Chang, S. X., Burkhardt, K. D., Mazur, L., Jones, E. L., Saponaro, P., LaChapell, D., Baynes, D. C., & Adams, R. D. (2011). The challenge of maximizing safety in radiation oncology. *Practical Radiation Oncology*, 1(1), 2–14.
<https://doi.org/10.1016/j.prro.2010.10.001>
- Mettler Jr, F. A., Huda, W., Yoshizumi, T. T., & Mahesh, M. (2008). Effective doses in radiology and diagnostic nuclear medicine: A catalog. *Radiology*, 248(1), 254–263.
<https://doi.org/10.1148/radiol.2481071451>
- Ministry of Public Health. (2015). *Koomeu gaan okbaep aa-kaan lae sa-paap waetlom sa-taan bor-ri-gaan suk-ka-paap* [General guidelines to designing healthcare buildings and environment].
https://dcd.hss.moph.go.th/web/attachments/article/266/210917_053752.pdf
- Ministry of Public Health. (2016). *Koomeu gaan okbaep aa-kaan lae sa-paap waetlom sa-taan bor-ri-gaan suk-ka-paap* [General guidelines to designing healthcare buildings and environment].
https://hss.moph.go.th/fileupload_doc_slider/2016-11-16--158.pdf
- Ministry of Public Health. (2021). *Koomeu kwaam bplotpai taang hong bpadtibatgaan daan rangsee* [Radiation laboratory safety manual].
<https://www.dmsc.moph.go.th/th/download/306/km/119>
- Ministry of Public Health. (2024). *Phaenkan pongkan lae khuapkhum rong mareng haeng chat* [National cancer control programme].
<https://www.nci.go.th/doc/cc/67-75.pdf>
- Ostlund, U., Kidd, L., Wengstrom, Y., & Rowa-Dewar, N. (2011). Combining qualitative and quantitative research within mixed method research designs: A methodological review. *International Journal of Nursing Studies*, 48(3), 369–383.
<https://doi.org/10.1016/j.ijnurstu.2010.10.005>
- Prugsiganont, S., & Jensen, P. A. (2019). Identification of space management problems in public hospitals: The case of Maharaj Chiang Mai Hospital. *Facilities*, 37(7/8), 435–454.
<https://doi.org/10.1108/F-01-2018-0001>
- Rostenberg, B., & Horii, S. C. (2006). *The architecture of medical imaging: Designing healthcare facilities for advanced radiological diagnostic and therapeutic techniques*. Wiley.
- Viryasiri, T., Laovisutthichai, V., Sangnin, K., Dhanakoses, K., Roopkaew, P., & Viryasiri, P. (2024). Hospital design principles implementation: Reflections from practitioners in Thailand. *Journal of Asian Architecture and Building Engineering*, 23(1), 43–56.
<https://doi.org/10.1080/13467581.2023.2215842>
- Wardhani, D. K., Hanan, H., & Firmansyah (2026). Sustainable architecture practice in Indonesia: Navigating global standards and local knowledge. *Nakhara: Journal of Environmental Design and Planning*, 25(1), Article 608.
<https://doi.org/10.54028/NJ202625608>
- Waroonkun, T., & Prugsiganont, S. (2022). Preventing the spread of COVID-19 through environmental design in Thai community hospitals. *Frontiers in Built Environment*, 8, Article 947211.
<https://doi.org/10.3389/fbuil.2022.947211>

Wiriyakraikul, C., Amatyakul, W., & Dhanakoses, K. (2022). The design of physical components of endoscopy units: A case study of four major public hospitals in Thailand. *Nakhara: Journal of Environmental Design and Planning*, 21(1), Article 202.
<https://doi.org/10.54028/NJ202221202>

World Health Organization. (2025). *Cancer*.
<https://www.who.int/news-room/fact-sheets/detail/cancer>

APPENDIX

Appendix A

Examples of ROD Design Guidelines

Space	Requirement	Context
1. Reception and waiting area		
1.1 Waiting area	• Support for wheelchair and stretcher patients with IV poles and oxygen tanks • Minimum area of 1.50 sqm per seat and 3.00 sqm per wheelchair user • Allocation of at least 10% of seating for wheelchair users	UK
	• Separation of inpatient and outpatient waiting areas • Capacity for one accompanying person per outpatient	USA
	• Barrier-free access for patients and visitors • Decentralized secondary waiting areas to reduce congestion • Consideration of patient waiting time in spatial planning • Dedicated areas for wheelchair and stretcher users • Access to natural daylight in the waiting area • Optional waiting area for children • Optional amenities such as vending machines, drinking water dispensers, and televisions, as appropriate	Worldwide
	• Minimum area of 20.00 sqm • Minimum area of 1.20 sqm per seat and 1.50 sqm per wheelchair user • Allocation of space for volunteers or stretcher staff	Australia
	• Area size determined by maximum seating capacity required • Minimum area of 1.00 sqm per seat, 2.00 sqm per wheelchair user, and 3.00 sqm per stretcher user	Thailand
1.2 Reception desk	• Barrier-free access for patients and visitors • Clear visibility of entrance and waiting area	UK
	• Controlled access to other areas	USA
	• Proximity to main entrance, distribution point to other departmental areas • Reception staff allocation at a ratio of 1:2 per radiation oncologist • Separate financial service area for privacy • Provision of a server room for patient data backup	Worldwide
	• Minimum area of 10.00 sqm • Barrier-free access for patients and visitors • Accommodation for patients with different levels of accessibility	Australia
	• Area size determined by number of working staff • Easy access from the waiting area • Minimum area of 1.50 sqm per file cabinet or computer desk, and 4.50 sqm per work desk and chair set per user	Thailand

Appendix A (Continued)

Space	Requirement	Context
1.3 Toilet		
1.3.1 Public toilet	• Two rooms, minimum area of 4.00 sqm per room • Optional toilets, separated by gender or shared • Minimum area of 4.00 sqm per room	Australia
	• Total area determined by number and type of sanitary fixtures • Easy access from waiting area • Minimum area of 1.50 sqm per sanitary fixture	Thailand
1.3.2 Accessible toilet	• One room, minimum area of 6.00 sqm per room • Optional shared facility with adjacent areas	Australia
	• Total area determined by number and type of sanitary fixtures • Easy access from waiting area • Minimum area of 4.50 sqm per accessible toilet	Thailand
2. Patient consult area		
2.1 Waiting area	• Accommodation for wheelchair and stretcher patients	UK
	• Optional shared area with adjacent areas	Australia
2.2 Reception	• Separate reception desk from main reception and waiting area	Worldwide
2.3 Consult/exam room	• Multipurpose consultation room for patients, e.g., nutrition counseling • Accessible design for wheelchair and stretcher patients • Optional anesthesia area for pediatric patients	UK
	• Equipped for general, gynecological, and ENT examinations, with necessary diagnostics • Located adjacent to radiation therapy room	Worldwide
	• Room size to accommodate 2–3 chairs for patients and relatives • Number of rooms determined by consulting staff	Worldwide
	• Easily accessible for outpatients without passing through treatment areas • Two rooms required, each with a minimum area of 14.00 sqm	Australia
2.4 Interview room	• Room accommodating at least 8 people, including patients and relatives • One room, minimum area of 12.00 sqm	Australia
2.5 Procedure room	• Room equipped with desks, chairs, exam beds, sinks, height measurement tools, medicine cabinets, and procedural devices, e.g., blood pressure monitors	Worldwide
	• One room, minimum area of 20.00 sqm	Australia
2.6 Toilet	• Optional shared facility with adjacent areas	Australia

Appendix A (Continued)

Space	Requirement	Context
3. Treatment planning and appliance areas		
3.1 Waiting area	• Design respecting patient privacy and confidentiality	Worldwide
	• Optional shared area for two radiation simulation rooms	Australia
	• Minimum area of 5.00 sqm	
	• Total area determined by number and type of sanitary fixtures • Easy access from main hallway	Thailand
3.2 Resuscitation trolley bay	• Minimum area of 1.50 sqm	UK
3.3 Clean-up room	• Room for storage of fixation device and patient mold equipment • One room, minimum area of 7.00 sqm	Australia
3.4 Mold room-fitting	• Room for manufacturing patient restraint devices (e.g., immobilization masks, vacuum bags) • Convenient wheelchair and stretcher access and storage for personal belongings • Well-ventilated, comfortable space with ceiling focal points, equipped with a hot-water sink, washbasin, mirror, shelving, and clothes hangers • Non-slip linoleum or vinyl flooring for easy cleaning • Radiation-positioning lasers installed at the same height as those in the treatment room	UK
	• Production of customized patient restraint devices (e.g., face masks) • Proper ventilation system	Worldwide
	• Room accommodating wheelchairs and positioning equipment • One room, minimum area of 10.00 sqm	Australia
3.5 Mold room-workshop	• Separation of clean and dirty zones for plaster casting in immobilization device fabrication • Space allocation for vacuum-forming machine with appropriate ventilation • Non-slip flooring • Radiation positioning lasers installed at treatment room height	UK
	• Adequate room ventilation • Patient bed provided if immobilization devices fabricated within the room • Sufficient space for equipment, countertop work areas, and storage for tools and materials	Worldwide
	• Acoustic insulation to reduce noise during mold-making processes • Specialized ventilation system for fabrication of photon blocks and electron shielding devices (molten metal, foam cutting, vacuum-forming) • One room, minimum area of 20.00 sqm	Australia

Appendix A (Continued)

Space	Requirement	Context
3.6 Patient changing	• Location near radiation simulation room • Minimum two rooms, accommodating seated, wheelchair, and stretcher patients • Changing area with direct access to radiation simulation room without returning to waiting area • Separate changing rooms for male and female patients	UK
	• Total area determined by number of locker units and changing rooms for peak usage • Easy access from main circulation routes and waiting area • Minimum area of 2.50 sqm per user or room	Thailand
3.7 Service	• Room size allowing maintenance access • Controlled access at all times • Fireproof and waterproof room design	Worldwide
	• Area allocation of one equipment room per radiation simulation room • One room, minimum area of 40.00 sqm	Australia
3.8 Radiotherapy simulator room	• Changing room, patient preparation area, and waiting area for CT scan room • Scanner positioned at 30-degree angle to control table to avoid obstructed head view • Patient restroom near CT scan room for abdominal examinations • Two-way communication system between CT scan room and control room • Sufficient space for equipment installation and maintenance	USA
	• Room design based on equipment type (CT scanner or MRI) with safety measures against radiation or magnetic fields • Storage space for accessories (e.g., quality assurance tools) in cabinets or shelves • Equipment positioning based on room layout or staff preferences and working habits • Convenient access to simulation equipment for wheelchair and stretcher patients	UK
	• Radiation shielding integrated into walls (lead, concrete, or brick) • Installation of "X-Ray On" light, radiation warning signs, two-way communication, and emergency stop button	Worldwide
	• Room size sufficient for simulation equipment • Dedicated storage for fabrication tools and equipment if immobilization devices are made in the room • Handwashing sink installation • Viewing window from control room into simulation room	Worldwide

Appendix A (Continued)

Space	Requirement	Context
	• Radiation shielding equivalent to X-ray protection • Room equipped with fluoroscopy equipment and CT scanner or CT simulator • Brick or reinforced concrete walls (230 mm) with lead-shielded door • Internal room dimensions matching treatment room (7 x 7 x 4 m)	Worldwide
	• Room size appropriate for equipment • One room, minimum area of 40.00 sqm	Australia
	• Wall thickness preventing radiation leakage $\leq 100 \mu\text{Gy}$ per week • Room dimensions considering usable space and workflow efficiency	Thailand
	• CT or MRI room minimum internal dimensions of 5 x 6 m (W x L) • MRI simulation rooms with copper-lined walls • CT scan rooms with solid, reinforced, or lead-lined brick walls • Easy access from waiting area • Minimum area of 30.00 sqm	Thailand
3.9 Radiotherapy simulator control room	• Control room positioned at foot end of CT scanner for clear head observation • Control room window bottom edge low enough for technologist to observe patient while seated	USA
	• Room adjacent to radiation simulation room • Viewing window into simulation room • Adequate work desks for staff	UK
	• Room adjacent to radiation simulation room • Patient observation window between control and simulation room made of lead glass embedded into wall	Worldwide
	• Patient observation window between control and simulation room made of lead glass embedded into wall	Worldwide
	• One control room serving two simulation rooms • One room, minimum area of 17.00 sqm	Australia
	• Observation window of radiation-shielding lead glass equivalent to 1.5–2 mm lead • Minimum observation window size of 0.30 x 0.30 m or 0.45 x 0.45 m • Minimum area of 6.00 sqm	Thailand
3.10 Radiotherapy treatment planning	• Quiet location, free from disruptive noise	UK
	• Location close to simulation room (not necessarily adjacent) • Room size sufficient for treatment planning computers and equipment	Worldwide
	• Sufficient space for computer workstations	Worldwide

Appendix A (Continued)

Space	Requirement	Context
	• Workspace for 6–10 people • One room, minimum area of 35.00 sqm • Workspace accommodating computer equipment placement • Brachytherapy treatment planning area included if services provided	Australia
3.11 Store - equipment	• Large storage room for materials, equipment, and molds • One room, minimum area of 20.00 sqm	Australia
3.12 Store - general	• One room, minimum area of 9.00 sqm	Australia
3.13 Accessible toilet	• One room, minimum area of 6.00 sqm	Australia
4. Medical physics area		
4.1 A medical physicist or a biomedical engineer room	• Single-occupancy workspace for one staff member with separate areas for medical physicist and biomedical engineer • 3 rooms, minimum area of 5.50–12.00 sqm per room	Australia
4.2 Physics laboratory	• Facility for fabrication of devices for energy calibration or patient immobilization • One room, minimum area of 24.00 sqm per room	Australia
	• Storage space for radiation dose calibration equipment (phantoms)	UK
4.3 Store - equipment	• Storage room for physics instruments (e.g., large water tanks, phantom models) • One room, minimum area of 20.00 sqm per room	Australia
4.4 Workshop - biomedical	• One room, minimum area of 40.00 sqm per room	Australia
5. Radiation therapy treatment areas		
5.1 Waiting area	• Provision of sub-waiting areas for each treatment room	UK
	• Seating capacity for approximately 12 patients per treatment unit • Allocation of space for 3 stretcher patients, separated from the general waiting area	Worldwide
	• Provision of at least 1 space for a stretcher patient per treatment room • Consideration of local cultural practices in waiting area design (e.g., male/female separation)	Worldwide
	• Separate waiting areas for each radiation treatment room • Two rooms, minimum area of 5.00 sqm per room	Australia
5.2 Change cubicle	• Allocation of 1 electrical cabinet room per 1 radiation room • Two rooms, minimum area of 4.00 sqm per room	Australia
5.3 Interview room – family/large	• Optional shared facility with other departmental areas • Two rooms, minimum area of 12.00 sqm per room	Australia

Appendix A (Continued)

Space	Requirement	Context
5.4 clean-up room	• Minimum area of 3.00×3.00 m • Minimum area of 9.00 sqm • Room for storage of radiation dose measurement equipment	Worldwide
	• Area allocation of 1 room per 2 radiation rooms • One room, minimum area of 15.00 sqm per room	Australia
5.5 Patient changing	• Proximity of area to the radiation treatment room • Provision of at least 2 rooms accommodating both seated and bedridden wheelchair patients • Changing area with direct access to the treatment room, bypassing the main waiting area • Separate changing rooms for male and female patients	UK
	• Changing area located near the treatment room entrance • External changing rooms for reduced patient treatment time	Worldwide
	• Optional location of changing rooms outside the treatment room for faster turnover • Design ensuring patient privacy and confidentiality	Worldwide
5.6 Radiotherapy bunker room	• Room designed for radiation shielding • Sufficient room size for radiation therapy machine rotation and stretcher movement • Radiation maze entrance or shielded doors in case of space limitations • Shielding thickness and entrance design based on functional requirements of adjacent spaces • Consideration of patient privacy in access design to treatment room • Standardized storage areas within treatment rooms for staff efficiency • Recommended in-room amenities: - Toilet paper dispenser - Handwashing sink, shelving, and mirror - Patient chair - Coat hooks - Positioning lasers - Last-man-out button near maze entrance - Safety signage and warning lights - Emergency stop button for linear accelerator - Music player - CCTV camera - Two-way communication system with control room • Cautious installation of artwork to prevent distraction or interference with systems	

Appendix A (Continued)

Space	Requirement	Context
	• Radiation-shielding maze or direct access with shielded door • Specification of radiation shielding materials by medical physicist • Wall and ceiling decorations for patient anxiety reduction	USA
	• Room with radiation-proof concrete walls calculated per local regulations • Shielding for floor, ceiling, and walls, especially with 360° equipment rotation • Radiation-shielding maze at sufficient distance, or shielded door if space-limited • Installation of illuminated warning signs, radiation warning signs, last-man-out button, CCTV, two-way communication system, and emergency stop button	Worldwide
	• Sufficient room size for equipment and full motion range • Door design to prevent unauthorized access • Adequate storage space for treatment equipment, immobilization devices, and QA tools • Entrance via large electric door or radiation maze	Worldwide
	• Recommended location of room above ground level • Rainproof design to prevent leakage and water infiltration • Minimum recommended room size: 7.00×7.00 m, minimum height 4.00 m, including maze • Maze width of 2.00-2.20 m • Foundation frame for equipment: 6.00×2.00×0.30 m (L×W×D) • Restricted access to non-shielded roof areas • Detailed shielding calculations by medical physicist • Radiation measurement conduit with minimum 150 mm diameter	Worldwide
	• Room size and requirements as specified by manufacturer • Two rooms, minimum area of 128.00 sqm per room	Australia
	• Treatment room location in low-traffic area, preferably basement • Non-usage of radiation room ceiling as regular area • Room size determined by usability, safety, and staff workflow efficiency • Treatment room door with interlock and radiation-on indicator • CCTV installation to ensure no unauthorized presence during exposure	Thailand
5.7 Radiotherapy bunker control room	• Entrance visibility from control room • Visual protection from patient information/images in radiation room • Desk with minimum depth of 1 m for large computer systems	UK
	• Room spacious enough for control console and technologist workspace • Control room protection from direct primary radiation beam	Worldwide

Appendix A (Continued)

Space	Requirement	Context
	• Separate control room for each treatment machine • Space for two-way communication systems and CCTV monitors	Worldwide
	• Room size and requirements as specified by manufacturer • Two rooms, minimum area of 17.00 sqm per room	Australia
	• Room size determination based on usability, safety, and flexibility	Thailand
5.8 Holding/ recovery bay	• Area allocation: 2 beds per 1 radiation room • Two rooms, minimum area of 10.00 sqm per room	Australia
5.9 Toilet	• Separate male and female toilets • Two rooms, minimum area of 4.00 sqm per room	Australia
6. Brachytherapy suite		
6.1 Waiting area	• Optional shared area with adjacent areas	Worldwide
	• Separation of waiting areas for male and female patients • Two rooms, minimum area of 5.00 sqm per room	Australia
6.2 Anesthetic induction room	• One room, minimum area of 15.00 sqm per room	Australia
6.3 Brachytherapy bunker	• Provision of radiation-shielded maze entryway (corridor) • Installation of pre-installed oxygen and suction lines • Installation of CCTV and communication devices for patient monitoring and communication • Room and maze dimensions complying with equipment requirements for efficient patient movement • Allocation of direct and easy staff access to treatment room	UK
	• Design of room specifically for radiation shielding • Minimum internal room dimensions: 4.00×4.00 m, ceiling height 3.00 m, overall height 3.60 m • Radiation maze with minimum wall and ceiling thickness of 1.00 m and width of 1.80 m	Worldwide
	• Room size and requirements as specified by manufacturer • One room, minimum area of 128.00 sqm per room	Australia
6.4 Brachytherapy bunker control room	• Provision of workspace for patient monitoring and control • Proximity of room to brachytherapy room	UK
	• Room size and requirements as specified by manufacturer • One room, minimum area of 17.00 sqm per room	Australia
6.5 Change cubicle room	• One room, minimum area of 4.00 sqm per room	Australia
6.6 Clean-up room	• One room, minimum area of 10.00 sqm per room	Australia

Appendix A (Continued)

Space	Requirement	Context
6.7 Operating room	• Provision of CT or MRI machine for device placement verification with shielding or magnetic field containment as required • Optional allocation of brachytherapy area near CT or MRI room for shared facility use	Worldwide
	• Optional provision of room depending on facility design • Provision of separate device placement room if brachytherapy room unsuitable for surgical procedures • One room, minimum area of 42.00 sqm per room	Australia
7. Support areas		
7.1 Handwashing bay		Australia
7.2 Linen bay	• Allocation of 1 area per 2 radiation rooms • Minimum area of 2.00 sqm	Australia
7.3 Mobile equipment bay	• Allocation of 1 area per 2 radiation rooms • Provision of parking space for mobile equipment or wheelchairs • Minimum area of 4.00 sqm	Australia
7.4 Resuscitation trolley bay	• Allocation of 1 wheelchair parking space per 2 radiation rooms • Minimum area of 1.50 sqm	Australia
7.5 Clean utility	• One room, minimum area of 12.00 sqm per room	Australia
7.6 Cleaner's room	• One room, minimum area of 5.00 sqm per room	Australia
7.7 Dirty utility	• One room, minimum area of 12.00 sqm per room	Australia
7.8 Disposal room	• One room, minimum area of 8.00 sqm per room	Australia
7.9 Staff station	• One room, minimum area of 5.00 sqm per room	Australia
7.10 Store - equipment	• One room, minimum area of 10.00 sqm per room	Australia
8. Staff area		
8.1 Staff room	• One room, minimum area of 20.00 sqm per room	Australia
8.2 Staff shower room	• Separation of male and female rooms • Two rooms, minimum area of 3.00 sqm per room	Australia
8.3 Staff toilet	• Separation of male and female rooms • Two rooms, minimum area of 3.00 sqm per room	Australia
	• Total area determined by number and type of sanitary fixtures • Provision of easy access to toilets from various departmental work areas • Minimum area of 1.50 sqm per sanitary fixture • Minimum area of 4.50 sqm per accessible toilet	Thailand

Appendix A (Continued)

References:

Australia (IHFG, 2017)

Thailand (Ministry of Public Health [MOPH], 2015; Ministry of Public Health [MOPH], 2016; MOPH, 2021)

UK (DH, 2013)

USA (Rostenberg & Horii, 2006; VA, 2008)

Worldwide organizations (International Atomic Energy Agency [IAEA], 2008; International Atomic Energy Agency [IAEA], 2014; IAEA & WHO, 2021)