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REVIEW ARTICLE

Functional imaging and radionuclide therapy in Tanzania: A narrative review of service delivery amidst an epidemiological transition

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ABSTRACT

Introduction: Nuclear medicine plays a critical role in functional and molecular imaging for cancer and cardiovascular disease; however, its development in Tanzania remains limited despite increasing demand driven by non-communicable diseases.

Methods: A narrative review was conducted using literature from PubMed, Google Scholar, African Journals Online, and institutional reports covering 2010–2026. Thirty-two sources were included and analyzed thematically under workforce, infrastructure, radiopharmaceutical supply chains, policy and governance, and financing.

Results: Nuclear medicine services are concentrated in urban referral hospitals, with limited geographic coverage. Major constraints include shortages of specialized personnel, lack of structured training programs, limited availability of Positron Emission Tomography/Computerized Tomography and related hybrid imaging systems, dependence on imported short-lived radiopharmaceuticals, and insufficient integration into national health policy and financing mechanisms.

Conclusion: The growth of nuclear medicine in Tanzania is constrained by multiple interconnected health system challenges. Strengthening service delivery will require coordinated improvements in workforce training, imaging infrastructure, radiopharmaceutical logistics, and health system financing and governance.

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INTRODUCTION

The landscape of healthcare in Tanzania has undergone a profound transformation over the last two decades, marked by a decisive shift toward clinical specialization and the expansion of tertiary care infrastructure. Significant national investments have bolstered oncology services and modernized diagnostic departments with advanced structural imaging, such as computed tomography (CT) and magnetic resonance imaging (MRI) [1]. These advancements have positioned the country as an emerging hub for specialized medical services within the East African region [2, 3].

These institutional improvements are occurring against the backdrop of a critical epidemiological transition. Like many emerging economies, Tanzania now grapples with a dual burden of disease: while infectious conditions persist, there is a sharp rise in non-communicable diseases (NCDs), specifically malignancies and cardiovascular disorders [4, 5]. This shift in the national health profile necessitates a parallel evolution in diagnostic precision. Managing complex NCDs requires more than just anatomical detail; it demands functional and molecular insights to facilitate early diagnosis, accurate staging, and the monitoring of therapeutic responses.

In this clinical context, nuclear medicine serves as an indispensable pillar of modern medicine. By utilizing radioactive isotopes to visualize physiological processes at the cellular level, modalities such as Single-Photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET) allow for the detection of biochemical changes before they manifest as structural abnormalities. These capabilities are now integral to modern oncology, cardiology, and nephrology worldwide, directly informing chemotherapy, radiotherapy, and surgical planning [6, 7].

Despite these clear clinical advantages, nuclear medicine remains a peripheral component of the national diagnostic architecture [2, 8]. This disparity between the expanding healthcare infrastructure and the lagging capacity for functional imaging creates a "silent technology gap." This gap is not merely a matter of equipment scarcity; it is a systemic issue involving workforce production bottlenecks, fragile radiopharmaceutical supply chains, and limited policy prioritization. While strides have been made in cancer treatment, the lack of imaging symmetry risks suboptimal staging and therapeutic uncertainty.

This narrative review provides an analysis of the nuclear medicine landscape in Tanzania, identifying the interlocking drivers of the technological deficit and proposing strategic pathways for integrating these essential services into the evolving healthcare framework.

METHODS AND EVIDENCE SYNTHESIS

This narrative review synthesized evidence from peer-reviewed literature, grey literature, and national health reports on nuclear medicine in Tanzania and comparable low- and middle-income settings. A structured search was conducted in PubMed, Google Scholar, and African Journals OnLine (AJOL) using relevant keywords related to nuclear medicine, functional imaging, Tanzania, and radiopharmaceutical supply chains, combined with Boolean operators. Searches were limited to English-language publications from 2010 to 2026 and conducted between December 2025 and March 2026. Eligible sources included studies, policy documents, and technical reports addressing nuclear medicine infrastructure, workforce, radiopharmaceutical supply, financing, or regulatory governance. After removal of duplicates and screening of titles and abstracts, 19 published studies and 13 institutional or grey literature sources were included, yielding a total of 32 documents for synthesis.

Data were organized thematically across five health system domains: infrastructure, workforce, radiopharmaceutical supply chains, policy and governance, and financing. The synthesis was guided by a health systems perspective conceptualizing nuclear medicine as an integral component of service delivery for non-communicable diseases. As a narrative review, no formal critical appraisal framework was applied; however, included sources were assessed for methodological clarity, contextual relevance, and recency, with priority given to peer-reviewed and institutional evidence.

THE CURRENT LANDSCAPE OF NUCLEAR MEDICINE IN TANZANIA

The development of nuclear medicine services in Tanzania is currently in a nascent and highly centralized stage. While the broader national health system has seen significant investment in diagnostic imaging and oncology care, the expansion of nuclear medicine has not kept pace, resulting in a service footprint that is disproportionately small relative to the population's needs.

Service distribution and institutional capacity

Nuclear medicine services are primarily delivered through a limited number of tertiary facilities located in major urban centers. Key institutions currently providing or hosting these specialized

services include the Ocean Road Cancer Institute (ORCI) and Aga Khan Hospital in Dar es Salaam, and Bugando Medical Centre (BMC) in Mwanza [2, 9]. While these facilities serve as vital national referral hubs for oncology, their nuclear medicine capacity remains operationally constrained. The concentration of services in these two cities creates a significant geographical barrier for patients residing in peripheral regions. High costs associated with travel, accommodation, and complex referral logistics often delay or entirely prevent diagnostic evaluation, thereby reinforcing urban–rural inequities in access to advanced molecular imaging [9, 10].

Specialist workforce and training pipelines

Workforce scarcity represents a critical constraint in Tanzania's nuclear medicine services. At present, the country has seven registered nuclear medicine physicians serving a population of over 70 million people [8], corresponding to approximately 0.012 per 100,000 population. The Ministry of Health data similarly report seven physicians in post against an estimated requirement of thirty, all based in the public sector [11]. Regional comparisons indicate that Tanzania's physician numbers are higher than Kenya's reported three, but substantially lower than South Africa's approximately 65, highlighting marked intra-regional disparities in workforce development despite variable levels of infrastructure investment [12]. This shortage extends to allied cadres, including medical physicists, radiopharmacists, nuclear medicine technologists, and radiation safety officers, all of whom are essential for safe and effective service delivery.

A key driver of this deficit is the absence of structured in-country postgraduate training programs. Most specialists have instead been abroad through international fellowships, primarily supported by the International Atomic Energy Agency (IAEA) [3]. While these initiatives have contributed to initial capacity development, they remain insufficient to meet the workforce requirements for nation scale-up of services.

Technological infrastructure and clinical scope

The existing technological infrastructure is primarily limited to gamma cameras and SPECT systems located in national referral hospitals. Advanced hybrid modalities, particularly PET/CT, remains highly limited, with only one operational unit reported in institutional and IAEA sources [2, 9, 12]; this should be interpreted as the best available estimate rather than a verified national census.

Regionally, Tanzania reflects a broader continental pattern of limited PET/CT penetration. An IAEA-led survey reports nuclear medicine services in 29 African countries, with only a small proportion achieving more than one SPECT or SPECT/CT camera per million population, and no country exceeding one PET/CT unit per million inhabitants [12]. As a result, clinical services are largely limited to conventional studies, including thyroid uptake assessment, radioiodine therapy; bone scintigraphy; and renal scintigraphy.

Similarly, advanced applications such as PET-based oncologic staging, myocardial perfusion imaging, and theranostic radionuclide therapies are not routinely available. Consequently, capacity for high-resolution metabolic tumor characterization is constrained, restricting the use of nuclear medicine in treatment response assessment [2, 13].

DRIVERS OF THE NUCLEAR MEDICINE GAP

The limited integration of nuclear medicine in Tanzania reflects a combination of epidemiological, logistical, and policy-related constraints rather than a single limiting factor. Despite the expansion of tertiary oncology services and anatomical imaging, nuclear medicine development has remained comparatively slow, resulting in structural imbalance in the diagnostic capacity.

Epidemiological transition and diagnostic preparedness

The shift towards a dual burden of disease, including cancer and cardiovascular conditions [4, 5], requires corresponding development of functional and molecular imaging. Unlike communicable diseases, which are largely managed through laboratory testing and structural imaging, non-communicable diseases often require early functional assessment to detect metastases or myocardial ischaemia before anatomical changes become apparent on CT or MRI [14-16]. However, investment in imaging infrastructure in Tanzania has largely prioritized anatomical modalities, resulting in a gap between evolving disease patterns and available diagnostic technologies [17].

Oncology expansion and imaging asymmetry

Modern oncology increasingly depends on functional imaging, including PET and radionuclide techniques, for staging, treatment planning, response assessment, and detection of recurrence [18-20]. In Tanzania, limited access to these modalities has created an imbalance between expnading oncologic treatment services and diagnostic capacity. This contributes to potential under-staging and the need for external referral for advanced imaging, increasing costs and delaying care.

Radiopharmaceutical supply fragility

A defining operational constraint in Tanzania's nuclear medicine service, as in many African countries, is the full reliance on imported radioisotopes [21, 22]. In the absence of domestic production capacity, supply depends on complex and time-sensitive international supply chain. This dependence introduces logistical, regulatory, and operational vulnerabilities that limit service scale-up and constrain the effective utilization of installed equipment and trained personnel.

Many commonly used isotopes such as Technetium-99m and Fluorine-18 have short half-lives (6 hours and 110 minutes, respectively), making them highly sensitive to delays in customs, transport, or flight schedules [23, 24]. Such disruptions can compromise isotope viability and interrupt service continuity. Dependence on imported radiopharmaceuticals also exposes services to currency fluctuations, supplier pricing variability, and procurement delays, limiting affordability and scale-up within public financing system [23-26]. Consequently, even where equipment and trained personnel are available, constrained isotope availability restricts procedural capacity and perpetuates the diagnostic gap.

At the continental level, while Technetium-99m is broadly available across African nuclear medicine centres, access to advanced radiopharmaceuticals remains limited, with PSMA and somatostatin receptor agents available in fewer than ten countries and Lutetium-177 therapy in only seven [12].

Financial and policy prioritization

Nuclear medicine is a capital-intensive specialty requiring purpose-built, radiation-shielded facilities, specialized personnel, and sustained investment in radiopharmaceutical supply, maintenance, quality assurance, and radiation safety. In resource-constrained settings, investment tends to prioritize modalities such as CT and MRI due to their broader clinical applicability, lower regulatory demands, and more immediate clinical utility [17].

Nuclear medicine has also had limited explicit inclusion in national health strategic frameworks, including the Health Sector Strategic Plan (HSSP) and National Cancer Control Strategy [27, 28]. This limited policy visibility contributes to fragmented development, weak institutional prioritization, and constrained allocation of resources for infrastructure, recurrent radiopharmaceutical costs, and training programs. It also complicates regulatory coordination between oversight bodies and reinforces inequities in service distribution [29].

Regulatory and financial barriers

Nuclear medicine services operate within a stringent regulatory framework designed to ensure the safe handling, transport, and use of radioactive materials [30, 31]. In Tanzania, regulatory oversight by the Tanzania Atomic Energy Commission (TAEC) is central for the licensing, radiation protection and compliance requirements. While these measures are essential for patient and public safety, they also introduce administrative and operational requirements that may affect service implementation, particularly in the context of time-sensitive radiopharmaceutical supply chains. Ensuring efficient regulatory coordination is therefore an important consideration for the expansion of nuclear medicine services.

Economic constraints further limit the expansion of nuclear medicine services. High capital and operating costs, coupled with expenditure on radiopharmaceuticals, equipment maintenance, and specialized personnel, create substantial financial barriers to service development. In addition, limited reimbursement mechanisms for nuclear medicine procedures, including through the national health financing schemes, may constrain cost recovery and reduce incentives for investment by both public and private providers. These challenges restrict service expansion despite the growing clinical demand for functional and molecular imaging [32].

DISCUSSION AND STRATEGIC DIRECTIONS

The findings of this review suggest that the nuclear medicine gap in Tanzania is driven by interrelated constraints in workforce capacity, infrastructure, radiopharmaceutical supply, financing, and policy prioritization. These constraints are structurally interconnected, such that weaknesses in one domain reinforce limitations in others, and therefore require a coordinated health systems response. Evidence from similar low- and middle-income settings [12] further indicates that isolated investment in equipment or infrastructure is unlikely to translate into sustained service delivery in the absence of parallel investments in human resources, financing mechanisms, supply chain resilience, and regulatory coordination.

Workforce scarcity emerges as the most fundamental constraint to service expansion. Although overseas fellowships have supported the development of an initial cohort of specialists, they have not established sufficient domestic training capacity to support scale-up, and they remain dependent on external funding structures that may not be sustainable. A domestic postgraduate training pathway, such as a master of medicine

(MMed) in Nuclear Medicine, may therefore represent a long-term strategic direction. However, its feasibility is contingent on the availability of qualified faculty, adequate clinical case volumes, and supporting infrastructure, suggesting that a phased model combining local training with structured international mentorship may be more realistic in the short to medium term. Importantly, workforce planning must extend beyond physicians to include medical physicists, radiopharmacists, technologists, and radiation safety personnel, as deficiencies in these cadres risk creating infrastructure that is technically available but operationally non-functional. Regional collaboration with established African training centres may provide an important transitional mechanism, but such arrangements should complement rather than substitute domestic capacity development.

These human resource constraints are closely linked to limitations in infrastructure and service distribution. Phased expansion of hybrid imaging, particularly PET/CT, at zonal referral hospitals could improve access to metabolic imaging for oncology staging and treatment planning. However, the utility of such investments is dependent on the presence of trained personnel and integrated diagnostic pathways, without which utilization may remain suboptimal. Similarly, decentralization of basic nuclear medicine services through satellite SPECT facilities may improve geographic access and reduce patient travel burden, but carries a risk of underutilization if not supported by maintenance systems, workforce distribution, and radiation safety capacity. These considerations highlight that infrastructure expansion must be understood not as an isolated technological investment, but as part of a broader system capacity to absorb and sustain advanced diagnostic modalities.

Operational continuity is further constrained by radiopharmaceutical supply fragility. Dependence on imported short-lived isotopes such as Technetium-99m and Fluorine-18 introduces vulnerability to transport delays, customs procedures, and international scheduling disruptions, all of which can interrupt service delivery [12]. While short-term improvements may be achieved through enhanced logistics coordination and prioritization of customs clearance processes for medical isotopes, these measures remain dependent on wider transport and administrative system efficiency. In the longer term, regional production models, including shared cyclotron facilities or isotope production hubs within East Africa, may offer more sustainable solutions. However, such approaches require substantial cross-border regulatory harmonization, sustained demand, and long-term financial commitment, and should therefore be evaluated cautiously to avoid inefficient capital investment in underutilized infrastructure.

Beyond operational constraints, the limited visibility of nuclear medicine within national strategic health frameworks suggests insufficient prioritization within health system planning. Greater integration into national instruments such as the Health Sector Strategic Plan and the National Cancer Control Strategy could improve coordination across infrastructure, workforce, and consumable planning [27, 28]. Nevertheless, policy inclusion alone is unlikely to be sufficient unless accompanied by predictable financing mechanisms that support recurrent operational costs. The high capital and recurrent expenditures associated with nuclear medicine, particularly radiopharmaceutical procurement and specialist staffing, limit affordability within existing health financing structures. While expansion of national health insurance coverage could improve cost recovery and reduce out-of-pocket expenditure, such reforms must be balanced against fiscal constraints and competing health sector priorities, particularly given the relatively low service volumes characteristic of early-stage nuclear medicine systems. These observations suggest that sustainable development depends on alignment between policy priorities and financing mechanisms rather than ad hoc or episodic investment cycles.

Regulatory governance plays a complementary but distinct role in shaping service delivery. Nuclear medicine services operate within a stringent regulatory environment overseen by the Tanzania Atomic Energy Commission, which is essential for ensuring radiation safety and compliance with international standards. However, regulatory processes related to licensing and importation intersect directly with clinical timelines, particularly for time-sensitive radiopharmaceuticals. The effectiveness of nuclear medicine services therefore depends not only on the existence of robust regulatory frameworks, but also on the degree of coordination and efficiency in their implementation. Strengthening inter-agency collaboration and clarifying procedural pathways for medical isotopes may improve operational responsiveness while maintaining safety standards, reflecting the need to balance regulatory rigor with clinical urgency.

Finally, the review highlights limited availability of locally generated evidence to support planning, monitoring, and evaluation of nuclear medicine services in Tanzania. Current evidence is largely derived from regional or international contexts,

which may not fully reflect local system constraints and disease patterns. Strengthening health information systems to capture nuclear medicine activity could improve the availability of routine data for planning and evaluation, particularly if integrated into broader hospital information systems and supported by structured reporting mechanisms. However, such improvements would depend on broader digital health infrastructure and institutional capacity for data governance and use. In parallel, strengthening local research capacity would support context-specific evidence generation on service delivery models, workflow efficiency, and clinical outcomes, thereby complementing international evidence and enhancing the contextual relevance of health system planning.

Limitations of the review

This narrative review is subject to several methodological limitations inherent to its design. Unlike systematic reviews, no formal critical appraisal tools or protocol-driven selection frameworks were applied, which introduces the potential for selection bias in the identification and interpretation of evidence. Efforts were made to mitigate this through the use of transparent inclusion criteria and prioritization of peer-reviewed and institutional sources; however, some degree of subjectivity in evidence synthesis cannot be excluded. In addition, the evidence base on nuclear medicine in Tanzania remains limited and uneven. Several aspects of service delivery, particularly radiopharmaceutical logistics, workforce distribution, and service utilization patterns, are not supported by comprehensive national datasets and are instead derived from regional estimates or institutional reports. This limits the precision with which certain system constraints can be quantified. Furthermore, while the review incorporated literature from comparable low- and middle-income and sub-Saharan African settings to contextualize findings, differences in health system organization and resource availability may limit the direct transferability of some comparative observations to the Tanzanian context. Finally, the dynamic nature of nuclear medicine technologies and service expansion means that some developments may not be fully captured within the time frame of the included literature. As such, the findings should be interpreted as a synthesis of currently available evidence rather than a definitive or exhaustive account of nuclear medicine capacity in Tanzania.

CONCLUSION

This narrative review indicates that the limited integration of nuclear medicine within Tanzania's health system reflects a multifactorial and interdependent set of constraints rather than a single technical deficiency. Workforce shortages, radiopharmaceutical supply fragility, infrastructure limitations, regulatory processes, and financing constraints collectively shape the current restricted availability of functional imaging services. The findings further suggest that the growing burden of non-communicable diseases is increasingly misaligned with a diagnostic system that remains predominantly oriented toward anatomical imaging. This mismatch highlights the emerging role of molecular imaging as a complementary component of contemporary oncological and cardiovascular care, particularly for conditions requiring functional and metabolic assessment. Addressing these gaps will require coordinated, system-level interventions that extend beyond equipment procurement to include sustained investment in human resources, supply chain resilience, regulatory coordination, and health financing mechanisms. While incremental progress may be achievable through phased implementation, long-term advancement will depend on the extent to which nuclear medicine is integrated into broader national health planning and supported by stable operational capacity. Overall, the review underscores the need for a more integrated and systems-oriented approach to the development of nuclear medicine services in Tanzania, consistent with the evolving demands of its epidemiological transition.

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