THE EVOLUTION OF NUCLEAR MEDICINE IN THE REPUBLIC OF KOSOVO: FROM PLANAR GAMMA CAMERA IMAGING TO SPECT/CT AND PET/CT—INSTITUTIONAL CHALLENGES, TECHNOLOGICAL ADVANCEMENTS, AND FUTURE CLINICAL PERSPECTIVES

Ismet BAJRAMI[1,3,4,5*], Fakir SPAHIU[1,4], Rame MIFTARI[4,5], Luljeta ABDULLAHU[4], Aferdita BAJQINCA PAÇARIZI[4], Bajram KRASNIQI[4], Ylli KAÇIU[3,4], Armend JASHARI[2,4]

[1]*Faculty of Medical Sciences, Goce Delcev University, Stip, Republic of North Macedonia*
[2]*Alma Mater Europeae, Kosovo*
[3]*University of Business and Technology UBT Higher Education, Kosovo*
[4]*Department of Nuclear Medicine, University Clinical Center of Kosovo (QKUK), Prishtina, Kosovo*
[5]*Faculty of Medicine, University of Prishtina "Hasan Prishtina", Prishtina, Kosovo*
[*]*Corresponding author e-mail: ibajrami971@gmail.com, ismet_bajrami@yahoo.com*

Abstract

Nuclear medicine in the Republic of Kosovo has evolved over recent decades from conventional radionuclide techniques into an increasingly relevant diagnostic and clinical discipline. Since its establishment in 1987, the service has contributed to the implementation of functional imaging in Kosovo, particularly in the assessment of thyroid disorders, renal function, skeletal pathology, and other radionuclide-based clinical applications.

In its early phase, nuclear medicine practice was based on conventional equipment, including linear scanning systems, renal functional assessment devices, gamma counting technology, and later planar gamma camera imaging. These modalities enabled the introduction of routine procedures such as thyroid scintigraphy, liver and spleen scintigraphy, renal radionuclide examinations, and thyroid-related laboratory assessments. Over time, the service became an important national reference point for thyroid diagnostics and contributed to undergraduate, postgraduate, and specialist medical education.

Following the post-war reorganization of healthcare services, nuclear medicine continued to develop within the University Clinical Center of Kosovo. The introduction of gamma camera technology expanded diagnostic capacity and allowed broader use of planar scintigraphy in endocrine, renal, skeletal, cardiologic, and oncologic indications. Subsequent modernization with a dual-head gamma camera system further strengthened routine diagnostic practice and supported the standardization of imaging procedures.

The acquisition of PET/CT in 2024, followed by the installation of a triple-head SPECT/CT system in 2025, represented a defining stage in the technological advancement of nuclear medicine in Kosovo. This transition from planar functional imaging to hybrid imaging has improved anatomical localization, diagnostic confidence, and clinical interpretation. SPECT/CT is particularly valuable in parathyroid disease, skeletal pathology, thyroid-related disorders, and other conditions requiring precise anatomical correlation. PET/CT has expanded oncologic imaging by supporting disease staging, treatment planning, response assessment, follow-up, and multidisciplinary decision-making.

Although considerable progress has been achieved, several practical and institutional limitations persist. These include the need for continuous professional training, protocol standardization, quality assurance, reliable radiopharmaceutical supply, infrastructure development, and stronger integration of nuclear medicine into national diagnostic and therapeutic pathways. Future development should therefore be directed toward establishing a dedicated PET/CT center and introducing theranostic services, including Gallium-68 PSMA PET/CT and Lutetium-177–based radionuclide therapy, with the aim of advancing personalized oncologic care in Kosovo.

Keywords: Nuclear medicine; Kosovo; gamma camera; SPECT/CT; PET/CT; hybrid imaging; theranostics; Gallium-68 PSMA; Lutetium-177.

Introduction

Nuclear medicine is a medical specialty based on the use of radiopharmaceuticals for diagnosis, functional assessment, molecular imaging, and targeted radionuclide therapy. Unlike imaging modalities that primarily provide anatomical information, nuclear medicine evaluates physiological, metabolic, and molecular processes. This functional approach has made nuclear medicine an important component of modern clinical practice in endocrinology, oncology, nephrology, cardiology, orthopedics, and several other medical disciplines [1–4].

The development of nuclear medicine in the Republic of Kosovo reflects a gradual transition from basic radionuclide procedures to contemporary hybrid imaging. This evolution has occurred alongside institutional development, professional training, changes in healthcare organization, and the introduction of increasingly advanced imaging technologies. From early thyroid and renal examinations to SPECT/CT and PET/CT imaging, nuclear medicine has progressively expanded its clinical and diagnostic value.

The aim of this paper is to present the historical development of nuclear medicine in the Republic of Kosovo, describe the technological transition from planar gamma camera imaging to SPECT/CT and PET/CT, and discuss current institutional challenges and future clinical perspectives, including the potential development of theranostic services.

Historical Development of Nuclear Medicine in Kosovo

Nuclear medicine in the Republic of Kosovo was established in 1987 and gradually developed as a clinical and academic discipline. In its initial phase, the service was based on conventional radionuclide equipment and basic functional diagnostic procedures. The early technological infrastructure included linear scanning systems, renal functional assessment devices, gamma counting technology, and other equipment used for the first radionuclide-based diagnostic examinations in the country [5].

These early techniques enabled the performance of thyroid scintigraphy, liver and spleen scintigraphy, renal radionuclide studies, and thyroid-related laboratory assessments. Although limited by the technical possibilities of that period, these procedures represented an important step in the development of functional diagnostics in Kosovo. They provided clinical information that could not be obtained from anatomical imaging alone and created the basis for the subsequent expansion of nuclear medicine practice.

Thyroid diagnostics became one of the most important early areas of nuclear medicine activity. Through thyroid scintigraphy and related hormonal assessments, the service gradually became an important national reference point for thyroid disease evaluation. This role was particularly relevant in a healthcare environment where specialized diagnostic resources were limited and centralized expertise was required.

In addition to its clinical role, nuclear medicine contributed to medical education. Over time, the discipline became involved in undergraduate, postgraduate, and specialist medical training, supporting the preparation of physicians and healthcare professionals familiar with radionuclide-based diagnostic methods.

Post-War Reorganization and Institutional Development

Following the post-war reorganization of healthcare services, nuclear medicine continued its activity within the University Clinical Center of Kosovo. This period was characterized by institutional rebuilding, gradual professional consolidation, and the expansion of diagnostic services for patients.

The introduction of gamma camera technology represented an important step in the modernization of nuclear medicine practice. Compared with earlier linear scanning systems, gamma camera imaging enabled improved visualization of radiotracer distribution, more efficient image acquisition, and broader clinical application (Fig.1). This allowed wider use of planar scintigraphy in endocrine, renal, skeletal, cardiologic, and oncologic indications.

A further step in modernization was the installation of a dual-head gamma camera system (Fig 2). This technology strengthened diagnostic capacity and supported more standardized routine imaging protocols. It contributed to the performance of bone scintigraphy, thyroid imaging, renal studies, parathyroid scintigraphy, myocardial perfusion imaging, and other functional examinations.

However, prolonged reliance on older equipment also created technical and operational limitations. Aging technology, maintenance difficulties, and the increasing complexity of clinical indications highlighted the need for further modernization and investment in hybrid imaging infrastructure.

Figure 1. Single-head SOFA gamma camera used at the Department of Nuclear Medicine, University Clinical Center of Kosovo, for planar scintigraphic imaging and routine radionuclide diagnostic procedures.

Figure 2. Conventional dual-head gamma camera system installed in 2009, used for planar scintigraphic imaging in nuclear medicine. Courtesy of the Department of Nuclear Medicine, University Clinical Center of Kosovo, Prishtina.

From Planar Imaging to Hybrid Imaging

Planar gamma camera imaging played a central role in the development of nuclear medicine in Kosovo. It enabled routine functional imaging and provided clinically useful information across several diagnostic fields. Nevertheless, planar imaging has inherent limitations, including limited anatomical localization, superimposition of structures, lower spatial resolution compared with tomographic methods, and difficulty in characterizing small or ectopic lesions.

Hybrid imaging has transformed modern nuclear medicine by combining functional radionuclide imaging with anatomical information from computed tomography. SPECT/CT and PET/CT (Fig 3 and 4) improve lesion localization, diagnostic confidence, and clinical interpretation by integrating molecular or functional data with structural imaging [1–4].

The acquisition of PET/CT in 2024, followed by the installation of a triple-head SPECT/CT system in 2025, represented a significant technological advancement for nuclear medicine in Kosovo. This development marked a transition from predominantly planar imaging toward advanced hybrid imaging and brought local practice closer to contemporary international nuclear medicine standards.

Figure 3. Triple-head SPECT/CT system installed in 2025 at the Department of Nuclear Medicine, University Clinical Center of Kosovo, marking an important advancement from planar scintigraphy toward hybrid nuclear medicine imaging. Courtesy of Nuclear Medicine Department-Prishtina

Figure 4. PET/CT system installed in 2024 at the Department of Nuclear Medicine, University Clinical Center of Kosovo, marking an important step toward advanced molecular imaging and personalized oncologic care in Kosovo. Courtesy from Nuclear Medicine Department-Prishtina

Clinical Value of SPECT/CT

SPECT/CT expands the diagnostic value of conventional scintigraphy by combining tomographic functional imaging with anatomical localization. This is particularly important when planar findings are equivocal, when lesions are small, or when abnormal tracer uptake is located in anatomically complex regions (Fig 3).

In parathyroid disease, SPECT/CT improves localization of hyperfunctioning parathyroid tissue and supports surgical planning, particularly in cases with ectopic glands, coexisting thyroid nodularity, or inconclusive planar imaging. International recommendations emphasize the value of combining functional and anatomical imaging for precise localization in patients with hyperparathyroidism [1,2].

In skeletal imaging, SPECT/CT helps correlate radiotracer uptake with anatomical findings (Fig 5), improving differentiation between degenerative, traumatic, inflammatory, and malignant lesions. EANM guidance highlights the role of optimized bone scintigraphy protocols and the added value of hybrid imaging in selected clinical scenarios [3].

SPECT/CT also has clinical utility in thyroid-related imaging, renal applications, sentinel lymph node procedures, infection and inflammation imaging, and selected oncologic indications. By improving anatomical correlation, SPECT/CT increases the clinical relevance of nuclear medicine findings and supports multidisciplinary decision-making.

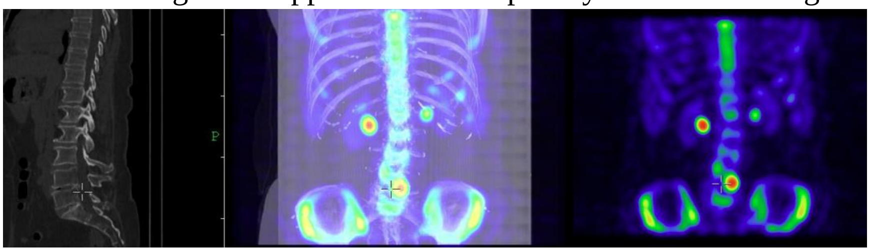

Figure 5. SPECT/CT bone imaging showing focal pathological radiotracer accumulation at L5, with fused anatomical and functional imaging enabling precise lesion localization.

Clinical Value of PET/CT

PET/CT is one of the most important developments in contemporary molecular imaging. By integrating metabolic or receptor-based information with anatomical imaging, PET/CT supports more accurate disease staging, restaging, treatment planning, therapy response assessment, and follow-up. In oncology, FDG PET/CT is widely used because it provides information on tumor metabolism and whole-body disease distribution [4].

The introduction of PET/CT in Kosovo represents an important advancement for cancer care. FDG PET/CT has broad clinical application in malignancies such as lymphoma, lung cancer, colorectal cancer, head and neck cancers, melanoma, gynecologic malignancies, and other oncologic conditions (Fig 6). It can influence patient management by detecting previously unrecognized disease, clarifying equivocal findings, assessing metabolic response, and supporting multidisciplinary therapeutic decisions [4].

Beyond oncology, PET/CT also has potential roles in infection, inflammation, cardiology, and neurology, depending on radiopharmaceutical availability, clinical protocols, infrastructure, and professional expertise. Therefore, the implementation of PET/CT represents not only a technological improvement but also a strategic step toward more comprehensive molecular imaging in Kosovo.

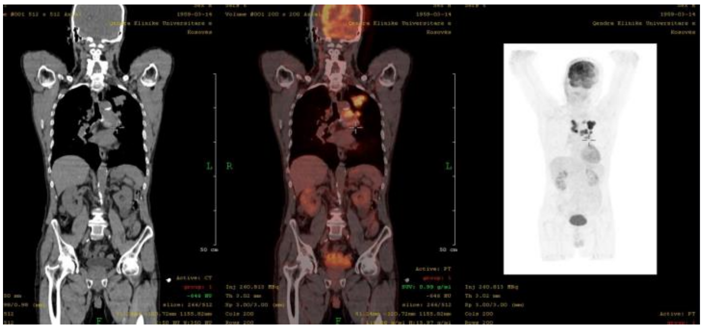

Figure 6. FDG PET/CT showing increased FDG uptake in the left lung and mediastinum, with fused imaging providing precise anatomical localization of metabolically active lesions.

Institutional and Professional Challenges

Despite significant progress, the development of nuclear medicine in Kosovo continues to face several challenges. Continuous professional training remains essential. The implementation of SPECT/CT and PET/CT requires expertise in image acquisition, reconstruction, interpretation, radiopharmaceutical handling, radiation protection, quality control, and structured reporting.

Protocol standardization is another important requirement. Standardized protocols improve reproducibility, diagnostic accuracy, patient safety, and comparability of results [5].

This is particularly relevant for PET/CT, SPECT/CT, parathyroid imaging, skeletal imaging, oncologic imaging, and future theranostic procedures.

A reliable radiopharmaceutical supply is fundamental for sustainable nuclear medicine practice. The availability of appropriate radiotracers determines the range of diagnostic and therapeutic services that can be offered. Interruptions in supply may limit clinical activity and delay patient care.

Infrastructure development is also necessary for the full implementation of modern nuclear medicine. This includes appropriate imaging rooms, radiation protection measures, hot

laboratory capacity, quality assurance systems, patient preparation areas, reporting infrastructure, data storage, and multidisciplinary communication pathways.
Finally, nuclear medicine should be more strongly integrated into national diagnostic and therapeutic algorithms. Collaboration with oncology, endocrinology, surgery, urology, nephrology, cardiology, radiology, and other specialties is essential to maximize the clinical benefit of nuclear medicine procedures.

Future Perspectives: PET/CT Center and Theranostics

The future development of nuclear medicine in Kosovo should focus on consolidating hybrid imaging services and expanding toward theranostic applications. A key strategic objective is the establishment of a dedicated PET/CT center capable of providing structured, standardized, and sustainable molecular imaging services.
Theranostics represents one of the most important directions in modern nuclear medicine, combining molecular imaging with targeted radionuclide therapy within the same biological pathway. This approach enables appropriate patient selection, treatment planning, therapy delivery, monitoring, and follow-up [6,7].
A particularly relevant example is the use of Gallium-68 PSMA PET/CT for prostate cancer imaging and Lutetium-177–based PSMA radionuclide therapy in selected patients with advanced prostate cancer. Traditionally, patients at high risk for metastatic disease have been evaluated with 99mTc-methylene diphosphonate bone scintigraphy and CT. However, PET radiopharmaceuticals have improved the assessment of disease extent. Although 18F-FDG PET/CT has limited value in prostate cancer staging, tracers such as 18F-fluciclovine, choline-based agents, and particularly PSMA-targeted imaging have expanded diagnostic possibilities in this field [8,9].
In this context, the introduction of Gallium-68 PSMA PET/CT and Lutetium-177–based PSMA therapy would represent an important step toward personalized oncologic care in Kosovo. These services would support more accurate staging, restaging, patient selection, and targeted treatment, while reducing the need for patients to seek advanced nuclear medicine procedures abroad. Future development may also include other theranostic radiopharmaceuticals and clinical indications, depending on infrastructure, regulatory approval, radiopharmaceutical availability, staff training, and institutional support.

Discussion

The evolution of nuclear medicine in the Republic of Kosovo illustrates the importance of technological development, institutional support, and professional expertise in building a modern diagnostic service. The transition from conventional radionuclide techniques to planar gamma camera imaging and then to hybrid imaging reflects a gradual but meaningful process of modernization.
The acquisition of PET/CT in 2024, followed by the installation of a triple-head SPECT/CT system in 2025, represents an important institutional and technological advancement, expanding the diagnostic possibilities available within the country. Hybrid imaging provides more precise anatomical localization, improves diagnostic confidence, and allows nuclear medicine findings to be more directly integrated into clinical decision-making.

However, technology alone is not sufficient. The successful implementation of modern nuclear medicine depends on trained personnel, standardized protocols, reliable radiopharmaceutical access, quality assurance, radiation safety, and institutional planning. Without these components, the full clinical potential of SPECT/CT and PET/CT cannot be achieved.
The future introduction of theranostic services would further strengthen nuclear medicine in Kosovo. By combining molecular imaging and targeted radionuclide therapy, theranostics supports a more personalized approach to cancer care and aligns Kosovo with contemporary developments in international nuclear medicine practice.

Conclusion

The development of nuclear medicine in the Republic of Kosovo represents a gradual transition from conventional radionuclide techniques and planar gamma camera imaging toward modern hybrid imaging with SPECT/CT and PET/CT. Since its establishment in 1987, the service has contributed to clinical diagnostics, thyroid evaluation, functional imaging, education, and specialist training.
The introduction of gamma camera technology, followed by dual-head gamma camera imaging, strengthened diagnostic capacity and expanded the clinical role of nuclear medicine. The acquisition of PET/CT in 2024, followed by the installation of a triple-head SPECT/CT system in 2025, marks a new stage in this development, offering improved anatomical localization, diagnostic confidence, oncologic staging, treatment planning, and multidisciplinary patient management.
Despite continuing institutional, technical, and professional challenges, current technological progress provides an important basis for future development. Establishing a dedicated PET/CT center and introducing theranostic services, including Gallium-68 PSMA PET/CT and Lutetium-177–based radionuclide therapy, should be considered key priorities for advancing personalized oncologic care and strengthening nuclear medicine in the healthcare system of Kosovo.

References

[1]. Greenspan BS, Dillehay G, Intenzo C, Lavely WC, O’Doherty M, Palestro CJ, et al. SNM practice guideline for parathyroid scintigraphy 4.0. J Nucl Med Technol. 2012;40(2):111–118. doi:10.2967/jnmt.112.105122.
[2]. Petranović Ovčariček P, Giovanella L, Carrió Gasset I, Hindié E, Huellner MW, Luster M, et al. The EANM practice guidelines for parathyroid imaging. Eur J Nucl Med Mol Imaging. 2021;48:2801–2822.
[3]. Van den Wyngaert T, Strobel K, Kampen WU, Kuwert T, van der Bruggen W, Mohan HK, et al. The EANM practice guidelines for bone scintigraphy. Eur J Nucl Med Mol Imaging. 2016;43:1723–1738.
[4]. Boellaard R, Delgado-Bolton R, Oyen WJG, Giammarile F, Tatsch K, Eschner W, et al. FDG PET/CT: EANM procedure guidelines for tumour imaging: version 2.0. Eur J Nucl Med Mol Imaging. 2015;42:328–354.
[5]. Clinical Service of Nuclear Medicine, University Clinical Center of Kosovo. Institutional historical record of the Clinical Service of Nuclear Medicine in Kosovo. Prishtina: University Clinical Center of Kosovo; internal archive.
[6]. Yordanova A, Eppard E, Kürpig S, Bundschuh RA, Schönberger S, Gonzalez-Carmona M, et al. Theranostics in nuclear medicine practice. Onco Targets Ther. 2017;10:4821–4828. doi:10.2147/OTT.S140671.
[7]. Sartor O, de Bono J, Chi KN, Fizazi K, Herrmann K, Rahbar K, et al. Lutetium-177–PSMA-617 for metastatic castration-resistant prostate cancer. N Engl J Med. 2021;385:1091–1103. doi:10.1056/NEJMoa2107322.

[8]. Czernin J, Allen-Auerbach M, Nathanson D, Herrmann K. PET/CT in oncology: current status and perspectives. Curr Radiol Rep. 2013;1:177–190, PMCID: PMC4034170 PMID: 24883234.

[9]. Jadvar H, Calais J, Fanti S, Feng F, Greene KL, Gulley JL, et al. Appropriate use criteria for prostate-specific membrane antigen PET imaging. J Nucl Med. 2022;63(1):59–68. doi:10.2967/jnumed.121.263262.