Current status of nuclear cardiology practice in Latin America and the Caribbean, in the era of multimodality cardiac imaging approach: 2022 update

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Cardiovascular diseases (CVDs) are the leading cause of mortality in Latin America and the Caribbean (LAC), with the risk in men being slightly higher than in women. The coronavirus disease 2019 (COVID-19) pandemic caused a significant reduction in the number of cardiovascular diagnostic procedures globally and in particular in LAC. Nuclear cardiology is available in the region, but there is variability in terms of existing technology, radiopharmaceuticals, and human resources. In the region, there are 2385 single photon emission computed tomography (SPECT) and 315 PET scanners, Argentina and Brazil have the largest number. There is an increasing number of new technologies such as cadmium–zinc–telluride (CZT) cardiac-dedicated gamma cameras, SPECT/computed tomography (CT), and PET/CT. All countries performed myocardial perfusion imaging studies, mainly gated-SPECT; the rest are multi-gated acquisition, mainly for cardiac toxicity; detection of viability; rest gated SPECT in patients with dilated cardiomyopathy, and bone-avid tracer cardiac scintigraphy for transthyretin cardiac amyloidosis diagnosis. Regarding other non-nuclear cardiac imaging modalities, Argentina, Colombia, and Chile have the highest ratio of CT scanners, while Brazil, Argentina, and Chile show the highest ratio of MRI scanners. The development of nuclear cardiology and other advanced imaging modalities is challenged by the high cost of equipment, lack of equipment maintenance and service, insufficient-specific training both for imaging specialists and referring clinicians, and lack of awareness of cardiology or other referring physicians on the clinical applications of nuclear cardiology. Another important aspect to consider is the necessity of implementing cardiac imaging multimodality training. A joint work of nuclear medicine specialists, radiologists, cardiologists, and clinicians, in general, is mandatory to achieve this goal. National, regional, and international cooperation including support from scientific professional societies such as the American Society of Nuclear Cardiology and Latin American Association of Biology and Nuclear Medicine Societies, cardiological societies, and organizations such as the International Atomic Energy Agency, and Pan American Health Organization, as well as government commitment are key factors in the overall efforts to tackle the burden of cardiovascular diseases in the region. Nucl Med Commun 43: 1163–1170 Copyright © 2022 The Author(s). Published by Wolters Kluwer Health, Inc.

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Introduction

Latin America and the Caribbean (LAC) have a population of over 650 million inhabitants, with roughly 80% concentrated in urban areas [1]. Life expectancy reaches...
atherosclerotic emergent risk factors [13]. In addition, dia, and gestational diabetes, recently considered among obstetric complications such as preeclampsia, eclampsia, and intrauterine growth restriction, show an increased risk of cardiac imaging for diagnosis and risk stratification. In the case of CVD in women, in addition to the value of traditional risk factors, new markers such as high-sensitivity C-reactive protein and detectable lipids may be considered. However, in some countries, the epidemiological situation is different, as is the case in Bolivia, where the most frequent CVD is Chagas’ cardiomyopathy, responsible for 60% of heart diseases [11,12].

In the case of CVD in women, in addition to the value of cardiac imaging for diagnosis and risk stratification, special attention should be paid to the adequate control of obstetric complications such as preeclampsia, eclampsia, and gestational diabetes, recently considered among atherosclerotic emergent risk factors [13]. In addition, some gynecologic pathologies such as early menopause and polycystic ovaries syndrome; autoimmune diseases, more frequent in women, and cardiotoxicity due to cancer treatments, should also be considered [5].

Appropriate use of cardiac imaging in the diagnosis and risk stratification of patients plays a significant role to reduce cardiovascular mortality, contributing to better patient management [14]. In this era of multimodality cardiac imaging, it is very important to assess which modality, for example, single-photon emission computed tomography (SPECT), cardiac computed tomography angiography (CCTA), PET, or cardiac magnetic resonance (CMR), among others can offer the best approach to cardiac care on a patient-centered basis. In this line, myocardial perfusion imaging (MPI) can be used as a gatekeeper to prevent patients from undergoing unnecessary invasive procedures, contributing to cost reduction, which is of particular importance in low- and middle-income countries (LMICs) where resources are limited.

Due to the burden of CVDs in Latin America and the Caribbean (LAC) and in order to support its Member States to tackle this health problem, placing special emphasis on addressing these conditions in women, the IAEA is currently implementing a regional ARCAL (Acuerdo Regional de Cooperación para América Latina) technical cooperation project entitled ‘Integrating Nuclear Medicine Techniques in a Multimodality Approach in Cardiology for Early Diagnosis and Risk Stratification of Cardiovascular Disease in Latin American Women (ARCAL CLXXXV)’, with the aim of offering the best possible education to cardiologists and nuclear medicine physicians and other related professionals involved in the management of patients with CVD, on the role of nuclear cardiology techniques in a multimodality approach for early diagnosis and risk stratification of IHD in women, as well as for the early detection of cardiotoxicity in oncologic female patients.

During the first coordination meeting of this regional project held in March 2022, the 14 participating countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Honduras, Mexico, Panama, Peru, Uruguay, and Venezuela) provided information on the practice of multimodality cardiac imaging practice during 2021. The data collected and included in this manuscript are an update of an article published by the IAEA in 2017 in the Journal of Nuclear Cardiology, resulting from a previous IAEA ARCAL project ‘Facing the high incidence of cardiovascular diseases in LAC through nuclear cardiology’ [15].

The opinions of various nuclear medicine experts and consultants from the region were also considered, as well as data published in 2021 by the IAEA on the status of nuclear medicine in LAC [16].
**Distribution of nuclear medicine resources**

According to the IAEA medical imaging and nuclear medicine global resources database - IMAGINE [17], the level of nuclear medicine equipment is variable across the LAC region. The approximate number of cameras in the Latin American and the Caribbean region is 2385 SPECT and 315 PET. Argentina and Brazil have the largest number (Argentina: 389 SPECT and 42 PET, and Brazil: 1333 SPECT and 146 PET). Table 1 shows the number of operating scanners per million inhabitants in the 14 LAC countries included in the present analysis. Argentina, Brazil, Uruguay, Colombia, and Chile have the highest ratio of nuclear medicine scanners.

In all these 14 countries, SPECT technology is dominant (range from 0.4 to 8.7 per million inhabitants), like the rest of the region, with an increasing number of new technologies such as cadmium–zinc–telluride (CZT) cardiac-dedicated gamma cameras, SPECT/CT and PET/CT. PET technology is steadily increasing (ranging from 0 to 0.9 PET cameras per million inhabitants). Cyclotrons are present in almost all countries (except in El Salvador, Honduras, and Venezuela), but still in a low number (Table 1), mainly for the production of fluorine-18 (¹⁸F).

Figure 1 shows the distribution of the utilization of radioisotopes and radiopharmaceuticals. All countries have technetium and use ⁹⁹m⁹⁹mTc-labeled compounds (either tetrofosmin or methoxy-isobutyl-isonitrile) for gated-SPECT MPI. Thallium-201 is scarcely used (14%) and is not available in most countries.

Regarding PET radiopharmaceuticals, although 85% of countries have ¹⁸F-Fluor-deoxy-glucose (FDG), it is mainly used for cancer studies. The utilization for cardiac purposes (viability/infection-inflammation) is still very limited. ¹³¹N-NH₃ is even less used in the region for myocardial perfusion studies due to difficulties in its production, requiring the most potent cyclotrons.

Data compiled during the first coordination meeting of the IAEA ARCAL regional project for CVDs in women in the 14 participating countries regarding the types of cardiac studies are presented in Fig. 2. This is referred to the capabilities of these countries to perform these studies, although in some cases are not used for these purposes. In general, all countries performed MPI studies, mainly gated-SPECT; less than 10% are multi-gated acquisition (MUGA), mainly for evaluation of cardiac toxicity in cancer patients, although the possibility of doing the study exists in 71% of countries. The remaining corresponds to other types of procedures, such as detection of viability, rest gated SPECT in patients with dilated cardiomyopathy (including intraventricular synchronism assessment), and bone-avid tracer cardiac scintigraphy for transthyretin cardiac amyloidosis diagnosis. Of note, this last procedure has been increasing during the last couple of years in the different countries of the region.

LAC initiative: AMILO-LATAM (Grupo Latinoamericano de Investigación en Amiloidosis Cardíaca/Latin American Research Group on Cardiac Amyloidosis) and American Society of Nuclear Cardiology (ASNC) webinars have contributed to the spreading of the technique and to increase its clinical impact in the region. A significant lack of awareness was identified among clinicians, although appropriate diagnostic resources are generally available. AMILO-LATAM data showed that very few patients are evaluated for wild-type transthyretin amyloid cardiomyopathy (ATTR-CM) in most Latin-American countries [18].

According to AMILO-LATAM researchers, these surveys indicate enough qualified professionals in Latin America to carry out imaging studies for cardiac amyloidosis following current guidelines, as well as necessary tracers and equipment (PY and SPECT), but some state-of-the-art technology [SPECT/CT, echo-strain imaging (ESI), CMR with parametric mapping (PM), and light-chains quantification] is lacking in some areas. Only 39% of scans are performed in high-complexity hospitals, which

| Scanners/per million inhabitants in country | CT scanners | MRI scanners | PET-CT scanners | SPECT cameras | Cyclotrons |
|-------------------------------------------|-------------|--------------|-----------------|---------------|------------|
| Argentina                                 | 42.3        | 14.5         | 0.9             | 8.7           | 0.2        |
| Brazil                                   | 22.1        | 15.3         | 0.7             | 6.3           | 0.1        |
| Chile                                    | 23.1        | 11.7         | 0.9             | 2.4           | 0.2        |
| Colombia                                 | 29.8        | 7            | 0.4             | 2.8           | 0.1        |
| Costa rica                               | 5           | 2            | 0.4             | 1.8           | 0.2        |
| Cuba                                     | 4.9         | 0.8          | 0.4             | 1.9           | 0.1        |
| Ecuador                                  | 2.4         | 1.2          | 0.1             | 0.6           | 0.2        |
| El salvador                               | 4.6         | 1.1          | 0               | 1.2           | 0          |
| Honduras                                 | 1.9         | 1            | 0.1             | 0.4           | 0          |
| Mexico                                   | 6.2         | 2.6          | 0.4             | 2.2           | 0.1        |
| Panama                                   | 9.2         | 2.8          | 0.7             | 2.4           | 0.2        |
| Peru                                     | 2.4         | 0.7          | 0.1             | 1.2           | 0.1        |
| Uruguay                                  | 13          | 2.9          | 0.9             | 4.9           | 0.3        |
| Venezuela                                | 0.36        | 0.12         | 0.2             | 0.6           | 0          |

CT, computed tomography; MRI, magnetic resonance imaging; PET, positron emission tomography; SPECT, single-photon emission computed tomography.

Source: https://iris.iaea.org, global resources database.

*Data provided by the national counterpart of the project.*
Fig. 1

Distribution of radioisotopes/radiopharmaceuticals/cyclotrons in the 14 countries included in the project. All countries have technetium and use $^{99m}$Tc-labeled compounds (either tetrofosmin or MIBI) for gated-SPECT MPI. Thallium-201 is scarcely used (14%). All 14 countries have $^{18}$F-FDG even though only 85.7% of countries have cyclotrons. Both countries without cyclotrons import $^{18}$F-FDG from neighboring countries and can perform PET studies. $^{18}$F-FDG, Fluor-deoxy-glucose. MIBI, methoxy-isobutyl-isonitrile; MPI, myocardial perfusion imaging; SPECT, single-photon emission computed tomography.

Fig. 2

Proportion of countries with nuclear cardiology techniques in Latin America and the Caribbean region. The figure is referred to the capabilities of these countries to perform these studies, although in some cases are not used for these purposes. In general, all countries performed MPI studies, mainly gated-SPECT; less than 10% are multi-gated acquisition (MUGA), mainly for evaluation of cardiac toxicity in cancer patients, although the possibility of doing the study exists in 71% of countries. The remaining corresponds to other types of procedures. MPI, myocardial perfusion imaging; SPECT, single-photon emission computed tomography.
could explain in part the limited accessibility to ESI and PM mapping in many centers [18]. Further education about red flags, diagnostic methods, and treatment algorithms are still necessary.

In 2019, it was estimated that over 820 solid-state dedicated cardiac CZT SPECT camera systems were in clinical use around the world [19]. CZT detectors are more expensive than NaI(Tl) crystal detectors but have an improved energy response, superior intrinsic spatial resolution, and increased sensitivity. Our survey showed that in 2022, the LAC region has 25 CZT detectors SPECTs for MPI (Brazil 18; Mexico 3; Argentina 2; and Costa Rica 2). As dynamic ⁹⁹mTc-sestamibi CZT-SPECT estimations of myocardial flow reserve are improving these cameras may offer a potential alternative to PET to evaluate diffuse atherosclerosis and coronary microvascular dysfunction that is prevalent among patients with cardiometabolic disease, which is common in the region [20].

Cardiac PET studies are still uncommon, both for viability and perfusion/myocardial blood flow measurement. This may constitute a potential area for development in the region, especially for the clinical management of women, considering the differences in the physiopathology of IHD compared to men (plaque erosion, distal embolization, abnormal coronary reactivity in women vs. plaque rupture in men) [21]. The management of microvascular disease, highly prevalent in women, can significantly benefit from the assessment of coronary flow reserve by PET MPI [22]. Although 78% of these 14 countries use ¹⁸F-FDG, it is not dedicated to cardiac studies but to cancer. Regarding PET myocardial perfusion with ¹¹N-ammonia, only 21% have the capability of performing the study and assessing myocardial blood flow (Fig. 2). In addition, ⁸²Rb PET is not available in the region, mainly because of higher radiotracer costs.

In general, physical stress is preferred when possible, according to the clinical condition of the patient, although in some countries dipyridamole is used in more than half of the patients. Some countries do not use pharmacological stress protocols due to high costs or lack of availability of pharmacologic stress agents. During the COVID-19 pandemic, there has been a shortage in the availability of these supplies.

Manpower and training in nuclear medicine

Table 2 shows the distribution of human resources per million inhabitants in the 14 countries included in the project. University-accredited programs for nuclear medicine physicians are available in Argentina, Brazil, Colombia, Chile, Mexico, Peru, Uruguay, and Venezuela, conferring a specialization degree or diploma in nuclear medicine. The existent programs have differences in duration, content, and professional requirements from country to country. In some cases, nuclear medicine can be considered a primary specialization, while in others, it is a subspecialty of internal medicine or radiology. Some nuclear medicine physicians working in nuclear cardiology hold another specialty, most frequently cardiology or internal medicine. In Mexico, there is a Postgraduate University Program for nuclear cardiology.

University degrees for technologists can be obtained in Argentina, Brazil, Chile, Colombia, Costa Rica, Cuba, Mexico, Peru, and Uruguay. The training does not only address nuclear medicine but also covers other areas of radiation medicine such as radiology and radiation oncology.

There is still a shortage of medical physicists and radiopharmacists in the region. Costa Rica, Cuba, Argentina, and Brazil are the countries with the largest number of physicists. Argentina, Brazil, Chile, Costa Rica, Cuba, Colombia, Mexico, and Venezuela have postgraduate training programs in medical physics, including Masters or PhD degrees. Data for the exact number of radiopharmacists were not provided. The availability of training programs has increased in the last few years, but the number of graduates still does not cover the needs.

In addition to available national training programs, all professionals involved in the practice of nuclear medicine can be trained on specific topics through many educational opportunities organized or sponsored by the IAEA, as well as by local or regional scientific societies and organizations, such as the Latin American Association of Biology and Nuclear Medicine Societies (ALASBIMN) and the ASNG.

### Equipment and type of cardiac imaging techniques other than nuclear medicine

Table 1 shows the number of operating scanners per million inhabitants in the 14 LAC countries included in the present analysis, including both nuclear and non-nuclear techniques. Regarding other non-nuclear cardiac imaging techniques, Argentina, Colombia, and Chile have the highest ratio of CT scanners, while Brazil, Argentina, and Chile show the highest ratio of MRI scanners. Of note, MRI and CT scanners (Figs 3 and 4, respectively), are managed mainly by radiologists, with the scarce contribution of cardiologists to the processing of this type of study.

### How to implicate nuclear cardiology into the multimodality approach on a regional basis

In the cardiological scenario of the LAC region, the development of nuclear cardiology and other advanced imaging modalities is challenged by many factors including the high cost of equipment, lack of equipment maintenance and service, insufficient specific training both for imaging specialists and referring clinicians and, in some cases, lack of awareness of cardiologists or other referring physicians on the clinical applications of nuclear cardiology.

Another important aspect to consider is the necessity of implementing cardiac imaging multimodality training in...
the countries of the region. A joint work of nuclear medicine specialists, radiologists, cardiologists, and clinicians, in general, is mandatory to achieve this goal. Crucial importance has for LAC countries, as LMICs, to carefully evaluate and select the most appropriate study, for example, echocardiography, SPECT, PET, CCTA, or CMR imaging, to be performed on each individual patient to optimize diagnosis, risk stratification, ischemia-guided therapies in IHD patients, and prognosis.

It is particularly important to include training in new imaging technology (CZT solid-state cardiac-dedicated gamma cameras, SPECT-CT, PET-CT, PET-MRI), as well as in cardiac CT and CMR. Critical components of the training for physicians dedicated to nuclear cardiology should include not only image interpretation skills and pathophysiology knowledge, but also physics, radiopharmacy, and quality assurance that allow them to certify and validate their knowledge. In this sense, the support of IAEA, ALASBMN, ASNC, as well as the national societies, is of crucial importance. Distance-assisted learning has been proven to be a very successful method to increase human capabilities during the COVID pandemic in 2020 and 2021, and it would be useful to continue developing.

CZT detectors SPECTs are becoming more prevalent in the region but are still concentrated in countries with higher incomes. CZT SPECT higher costs are still a significant limitation for the dissemination of this technique.
PET applications in cardiology should be made more available in the region, not only for viability assessment purposes with 18F-FDG, but also for myocardial blood flow evaluation for the detection of multivessel disease and microvascular angina. This last indication results are especially necessary when female patients are assessed [23,24].

In the region, patients with stable IHD frequently undergo revascularization without prior functional assessment [25]. Given that nuclear cardiology is an excellent tool for the appropriate selection of such treatment options, this provides a great incentive to integrate and strengthen the practice of nuclear cardiology in the LAC region. However, echo stress and CMR with stress can also be considered. Availability, costs, patients informed decisions and groups’ experience influence the clinical choice of the test.

The increase in the number of centers and equipment available in the region, with a clear trend toward the modernization of existing infrastructure, and technological transition that includes hybrid and non-hybrid imaging, new radiopharmaceuticals as well as the significant number of well-qualified, highly competent experts developing skills in quality assurance and safety programs in practice, is becoming a trend for future development in LAC. Much more is needed to fill the gaps in the region. One may speculate that a better socioeconomic situation will improve the status, as countries with more economic resources have more capabilities to acquire equipment and train personnel, but strategic decisions should be made to implement the changes required.

**Conclusion**

LACs are experiencing a great burden of CVDs, which account for the highest proportional mortality in the region. Cardiac imaging techniques, including nuclear, are much needed to address this health challenge. A multimodality imaging approach should be adopted to adequately managed CVDs and this should include not only the renovation and sustainability of medical equipment already installed but also the appropriate and continuous training of the professionals involved in the acquisition and processing of these studies.

National, regional, and international cooperation including support from scientific professional societies such as ASNC and ALASBIMN, cardiological societies, and organizations such as IAEA, and PAHO, as well as government commitment, are key factors that may serve as part of an overall effort to tackle the burden of CVDs in the region. When comparing the current status of nuclear cardiology practice in LAC, with international standards and recommendations established by the IAEA or other organizations [26–29], the need for more and better equipment, more radiopharmaceuticals, adequately trained professionals, more educational programs and quality assurance becomes evident.
Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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