Current Status of Nuclear Medicine Practice in Latin America and the Caribbean

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Nuclear Medicine Survey in Latin America

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ABSTRACT

The practice of Nuclear Medicine (NM) in the Latin America and the Caribbean region has experienced an important growth in the last decade. However, there is great heterogeneity among countries regarding the availability of technology and human resources. According to the data collected until the end of June 2014 by the IAEA the total number of gamma cameras in the region is 1231 with an average of 2.16 gamma-cameras per million inhabitants. Over 90% percent of the equipment is SPECT; 7.6 % of them with hybrid technology. There are 161 operating PET and/or PET/CT in 12 Member States, representing a rate of 0.3 per million population. Most of NM centres belong to the private health system and are located in capital and/or major cities.

Only four countries have the capability of assembling $^{99m}$Mo-$^{99m}$Tc generators and two countries produce $^{99m}$Tc from nuclear reactors. Cold kits are produced in some countries and therapeutic agents are mostly imported from outside the region. There are 35 operative cyclotrons. In relation to human resources: there is 1 physician per gamma-camera, 1.6 technologists per gamma camera, 0.1 medical physicists per centre and approximately 0.1 radiochemist/radiopharmacist per centre. Nearly 94% of the procedures performed are diagnostic. PET studies represent about 4% of the total.

The future of NM in the Latin American and Caribbean region is promising, with great potential and possibilities. We have found that some of the most important factors in order to drive the region towards greater homogeneity with regards to the availability and application of NM, and bridging the gaps between the individual countries in the region are the awareness of clinicians on the importance of NM techniques in the management of prevalent diseases in the region, increased capacity building and the continuous and strong
support of international organizations, such as the IAEA, through national and regional projects as well as strong public-private partnerships and government commitment.

Key words: Nuclear medicine, SPECT, PET, Latin America, radionuclides.

INTRODUCTION

Geographically, Latin America and the Caribbean refer to the whole of the American continent below the Rio Grande, including Mexico, Central America, the Caribbean islands, and South America. This region has a total population of over 600 million people, with almost 80% concentrated in urban areas. Literacy is above 91%, life expectancy reaches a mean of 75 years, and the average annual population growth rate is 1.1% across the region (1). The public expenditure in healthcare as % of GNP varies between 4.4 and 10.9 (2).

In the last decades, the Latin American and Caribbean region has experienced several social, demographic and economic changes that have led to a significant impact in public health. Population ageing and changes in lifestyle exert great pressure on the healthcare system due to the increasing prevalence of chronic diseases affecting elderly people. According to the 2012 statistics from the Pan American Health Organization (PAHO), the main causes of death in the region are cardiovascular diseases (especially ischemic cardiomyopathy) and several types of cancer (especially from lung, prostate, breast, and cervix, among others). These two causes account for about 50% of the deaths registered in the region, followed by accidents, and criminal violence (3). In this context, diagnostic and
therapeutic applications of nuclear medicine (NM) techniques gain vital importance and can be of great impact for the cost-effective management of most of these patients.

The goal of this report is to evaluate and describe the current status of NM practice in International Atomic Energy Agency (IAEA) Member States that participated in the Regional Technical Cooperation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean Region (ARCAL). Data were obtained until June 2014, from the IAEA’s Nuclear Medicine Database (NUMDAB), participants in coordination meetings of several on-going regional (RLA) projects, the Regional Strategic Profile (RSP) (4), and the opinion of various NM experts and consultants in the region.

TECHNOLOGY

The approximate total number of gamma-cameras in the region is 1231, with Brazil and Mexico being the countries with the largest number of machines (360 and 285 respectively). Haiti on the other hand has no NM services (Table 1).

The number of operating gamma-cameras per million inhabitants ranges from 0.0 to 6.7, with an average of 2.16 for the whole region; Argentina, Uruguay and Chile have the highest ratio, followed by Mexico and Panama (Fig. 1).

The technological characteristics of the installed equipment is quite variable (Table 1). There still some proportion of planar gamma-cameras; about 6%, most of them having surpassed the usual lifespan recomended by the manufacturers (5). However, a small number of these cameras are near state-of-the-art equipment, such as dedicated thyroid cameras or other small-field of view instruments designed for very specific imaging procedures. On the other hand, in countries such as Brazil, Chile, Colombia and Uruguay,
SPECT technology is clearly dominant or nearly exclusive. In total, about 93.5% of the instruments in the region are SPECT cameras, of which 7.6% use hybrid technology (SPECT/CT). Currently, the region has a high replacement rate of existing outdated technology, with increasing number of SPECT and SPECT/CT facilities (6).

Twelve of the 21 ARCAL Member States have PET and/or PET/CT equipment, for a total of 161 operating instruments, 90% of them are PET/CT systems (Fig. 2). During the last five years, a significant increase in the number of installed PET machines has been seen, with a growth of 88% between 2006 and 2009, 35% between 2009 and 2011, and 31% between 2011 and 2013.

The largest number of NM centers belong to the private sector (about 70%), despite the fact that healthcare is provided for the majority of the population by the public system. Regarding geographical distribution, in all countries NM facilities tend to be concentrated in capitals and large urban communities.

RADIOPHARMACY

The development of radioisotope production and radiopharmaceuticals in Latin America and the Caribbean is very heterogeneous.

Argentina, Brazil, Chile, México and Peru have nuclear reactors for research purposes, allowing the production of limited amount of medical radioisotopes. Only four countries have the capability of assembling $^{99}$Mo-$^{99m}$Tc generators, namely: Argentina, Brazil, Cuba, and Mexico, either through the import of fission $^{99}$Mo from outside the region, or through local production (Argentina). Brazil is the major producer of generators, with 18,236 units in 2012 (which represents 49% of the regional demand), followed by Argentina with 28%, Mexico with 6%, and Cuba with 2%. Peru and Chile produce $^{99m}$Tc from nuclear reactors.
As for the availability of cold kits for labelling with $^{99m}$Tc, they are produced by public institutions as in the case of Brazil, Chile, Cuba, Mexico and Peru, and by private companies in Argentina, Brazil, Chile, and Uruguay. Most manufacturers commercialize these products in their own countries as well as in the rest of the region. Of the 19 cold kits compounds produced in the region, MDP accounts for 37%, DTPA 16%, MIBI 15%, DMSA 11%, ECD and phytate 7%, and pyrophosphate and dextran 4%, while other formulations represent less than 10%. Production usually follows international standards. Most of the countries have radiopharmacy units at operational levels 1 or 2, following the IAEA’s classification criteria contained in the publication: Operational Guidance on Hospital Radiopharmacy A Safe and Effective Approach (7). Therapeutic agents are mostly imported from outside the region. Iodine-131, $^{153}$Sm, $^{66}$Ho are locally produced in Argentina, Brazil, Chile, Mexico and Peru.

There are currently at least 35 operative cyclotrons in the region, with a 300% growth of installed capacity between 2006 and 2013. As for the production of PET isotopes all the above mentioned cyclotrons are devoted to the production of fluorine-18 ($^{18}$F) and few are equipped to produce $^{11}$C, and $^{15}$N, $^{15}$O. Over 90% of the PET procedures are performed with $^{18}$F-FDG. However, there is an increasing utilization of other $^{18}$F-labelled tracers such as thymidine, choline, dopamine and acetate, among others. Recently, $^{68}$Ge-$^{68}$Ga generators have been introduced for labelling of somatostatin peptides analogues and are already available in Argentina, Chile, Colombia, Mexico and Uruguay.

**HUMAN RESOURCES AND EDUCATION**

**Nuclear Physicians**
There are approximately 1,264 NM physicians in the region; the number of physicians per gamma-camera varies between 0.5 to 2.3, with an average of 1 (Fig 3). Some NM physicians hold a second specialty, most frequently internal medicine, endocrinology, oncology, or cardiology. Recently, the introduction of hybrid modalities such as SPECT/CT and PET/CT has attracted radiologists to the field. The training of NM physicians in radiology is increasing.

Tertiary educational institutions with accredited programs for NM physicians are available in Argentina, Brazil, Colombia, Chile, Mexico, Peru, Uruguay, and Venezuela, conferring a specialization degree or diploma in NM. However, post-degree educational programs differ among these countries, being considered as primary specializations in some with a duration of three to four years, or as sub-specialties of internal medicine or radiology in others with an average duration of two years. In Venezuela, for example, training in this area is part of a broader program in radiation oncology, involving Radiotherapy and NM.

**Technologists**

Although not critical, the shortage of technologists is a common problem in the region. The number of technologists per camera varies between 0.4 and 4.3, with an average of 1.6 (Fig 3). The level of education and formal training is again quite varied across countries; formal university degrees can be obtained in Argentina, Brazil, Chile, Costa Rica, Cuba, México, and Uruguay (8). In most cases, the training is not focused on NM only, but covers in addition other areas of radiation medicine such as Radiology and Radiotherapy. Uruguay is the only country with a specific university degree for NM technologists. Nevertheless, the number of formally trained technologists does not generally meet the demand, and many positions are filled by personnel with training in other biomedical related areas. In Brazil,
for example, many technologist’s positions are occupied by licensed biologists or laboratory technicians, as is the case in Colombia where bacteriologists have specific training in nuclear medicine.

The increasing complexity of imaging equipment and software, as well as the introduction of hybrid technologies, entails a special challenge in this area of human resources. To deal with this problem, common to many Member States, the IAEA has introduced a worldwide Distance-Assisted Training (DAT) program for NM technologists. DAT contains a comprehensive on-line set of training resources covering basic sciences and clinical applications, with special attention on SPECT/CT and PET/CT (8). The program adopts a distance-learning approach to be conducted in the participating countries, and is designed in a way that students can learn and practice at their own working place under the supervision of a network of professionals that provide local support. In the case of Latin America, the program (originally in English) has been completely translated into Spanish and is accessible to all countries in the region, including Brazil where the native language is Portuguese. Courses have already been conducted, or are in progress, in most countries in the region; currently there are more than 200 students in 12 countries actively participating in the program. Feedback has indicated a significant gain in knowledge, development of problem-solving skills, and most importantly, a positive change in attitude and practice.

**Physicists**

Medical physicists have proved to be key members of the NM department due to their training in quality control and their general scientific approach to problems. They usually participate in several tasks (9) such as the establishment of institutional radiation protection programs, quality control of nuclear medicine instruments, optimization of NM clinical
procedures including acquisition and processing protocols, and more recently they have increased their activities by introducing clinical dosimetry in medical practice, in order to optimize radionuclide therapy in different clinical scenarios. Many post-graduate educational activities have been organized and carried out on these topics in the region, most of them sponsored by the IAEA.

However as for medical physicists with NM training, there is an overall shortage in the region. Only 12 out of 21 ARCAL Member States have medical physicists working in NM, with 0.1 medical physicist per centre. Argentina, Brazil, Cuba and Venezuela are the countries with the largest number of physicists, but only the last two have almost one professional per NM department (Fig 4). Some countries have postgraduate educational programs in medical physics, namely Argentina, Brazil, Chile, Costa Rica, Cuba, Colombia, México and Venezuela. Training programs have increased in the last few years, however the number of graduates does not cover the needs. The medical physicist is generally not recognized as a member of the healthcare team, and formal positions are usually nonexistent in most hospitals and institutions despite the need for their expertise in a variety of technical tasks. On the other hand, most of the medical physicists generally tend to dedicate themselves to other areas with more solid demand and better remuneration, such as in radiotherapy.

Radiopharmacists and radiochemists

In total, there are approximately 122 radiopharmacists/radiochemist in the region, distributed in 11 countries; corresponding to 0.1 radiopharmacist/radiochemist per centre (Fig 4), number that is far from ideal to cover the regional needs. Some Member States have strong university programs as is the case of Argentina, Brasil, Costa Rica, Cuba,
Mexico and Uruguay, with graduates having access to Master’s or PhD degrees in most cases. These professionals have contributed to the development of radiopharmacy in the region and the implementation of research activities in this field as well as the availability of cold kits and PET tracers. In countries without regular training programs, professionals working in the area have received their training abroad.

**Continuing Education**

Besides national educational programs, all professions involved in the practice of NM, have many educational opportunities through activities organized or sponsored by the IAEA as well as local or regional scientific societies, such as the Latin-American Association of Biology and Nuclear Medicine (ALASBIMN) that has a Continued Education Committee which organizes regular training courses during the congress that takes place every two years in different locations across the region.

The IAEA has played a relevant role in the improvement of human resources, sponsoring many regional and national training courses covering a wide variety of subjects, including topics such as basic sciences, technical and clinical issues, radiopharmacy, radiation safety, quality management, among others. A large number of NM professionals have been supported by the IAEA for training activities including international fellowships and scientific visits. More recently, the IAEA has established co-operation agreements and strategic partnerships with important international organizations such as the World Federation of Nuclear Medicine and Biology (WFNMB), the Society of Nuclear Medicine and Molecular Imaging (SNMMI), the European Society of Nuclear Medicine and Molecular Imaging (EANMMI) and the American Society of Nuclear Cardiology (ASNC), among others, has facilitated access for over 400 professionals to on-line trainings in
diagnostic CT and PET/CT and to over 1000 participants from the region to webinars and other Continuing Medical Education activities. It is expected that these educational activities will expand in the near future, reaching a broader range of professionals in the region.

**TYPES OF PROCEDURES**

Data obtained from NUMDAB, which represents about 10% of all NM departments in the region, shows that nearly 90% of procedures performed in a typical setting are diagnostic nuclear medicine procedures, excluding PET/PET-CT. Bone and cardiac studies are the most common procedures, with an average of 30% and 21% respectively, followed by endocrine and renal studies (Fig. 5). PET applications are growing very fast; currently, they represent about 4% of total NM. Although not specifically mentioned in the graphs, sentinel node detection is a rapidly growing technique as it is gaining acceptance among surgeons and oncologists. Regarding therapeutical applications: which account to 6% of the procedures, the vast majority implies the use of radioiodine for thyroid cancer and hyperthyroidism. However, there is an increased use of new therapeutical agents such as, $^{131}$I MIBG, somatostatine peptide analogues labeled with $^{177}$Lu or $^{90}$Y for neuroendocrine tumors, $^{90}$Y or $^{131}$I labeled anti-CD20 monoclonal antibodies for lymphoma and Alpha emmiter (223Radium-) for metastatic castration-resistant prostate cancer (CRPC).

**SCIENTIFIC SOCIETIES**

National NM societies are operative in Argentina, Brazil, Colombia, Chile, Mexico, Peru, Uruguay and Venezuela. They hold national meetings and other educational events on a regular basis including taking part in activities of other scientific associations. The region
has a society that unities most of the national entities; ALASBIMN was founded in 1964 and its permanent Secretariat is in Montevideo, Uruguay. Every two years the ALASBIMN organizes a conference, where professionals from the entire region convene to share the latest advances in nuclear medicine and molecular imaging. ALASBIMN has its own official peer-reviewed, open-access publication, ALASBIMN Journal (www.alasbimnjournal.net), which is published on-line and accepts articles either in Spanish or Portuguese and also in English.

**RESEARCH**

Even though many centers in the region have participated in Coordinated Research Projects organized by the IAEA, the research activities are mainly limited to university centers. Publications in peer-reviewed journals and presentations in international meetings coming from regional authors is relatively low. ALASBIMN encourages the presentation of research papers by issuing four types of awards to the best abstracts in Basic and Clinical Sciences, as well as for Technologists and Young Investigators, respectively. Since 2012, the SNMMI offers an award to the best abstract in oncology coming from a Latin-American country.

It is important to note that although limited to certain countries, there is preclinical imaging infrastructure for animal studies: 1 PET-SPECT-CT and 1 PET in México, 8 PET-SPECT-CT in Brasil and 1 PET-SPECT-CT in Uruguay.

**QUALITY PRACTICE**

Beside the national plans and regulations in some countries related to implementation of quality management in clinical practice, an effort to expand and consolidate quality practice...
in NM, has been developed by the IAEA. A quality audit program based on guidelines contained in a document prepared by a group of experts in the field, named QUANUM (Quality Management Audits in Nuclear Medicine Practices) (10) has been implemented in the region. With the support of IAEA multidisciplinary auditors teams have been trained, with the involvement of regional experts who have conducted audit missions to various countries, at the request of institutions. The aim of the audits is to identify problematic areas and to advise on how to improve the quality of practice. Up-to-date quality management systems in NM services have been implemented in most ARCAL Member States and over 1000 NM professionals have received training in this field.

DISCUSSION

The average number of gammacameras per million population in the region is 2.6 with a range of 0.0 to 6.7. This is lower than in Europe (average: 5.57, range: 0.0-26.46), the United States (47.2) or Canada (21.05)*1. The analysis of the status of NM in the Latin-American and Caribbean region leads to several observations. Some strengths can be identified, such as the availability of almost all current diagnostic and therapeutic applications of the specialty, endowing the region with the possibility of providing NM services in line with international standards. This is supported by a progressive technology growth, with a clear trend towards the modernization of existing infrastructure. In some countries, there is specific governmental support for the use of nuclear techniques in healthcare systems and there is interest both in the public and private sectors to invest in this area, as a tool to confront some of the most prevalent diseases (11). In addition, a significant number of well-qualified, highly competent experts are available in the region

and high level university training centres are able to provide specialized education to fellows in all areas of the specialty. The above mentioned strengths are reinforced through horizontal cooperation among countries, especially in development of human resources and the supply of consumables and radiotracers.

Several inter-institutional, national and international agreements are in place, resulting in an improvement in bilateral cooperation among countries. This is evidenced through the activities of scientific societies which play an important role in educational and strategic support, mainly through the organization of regular scientific events and CME activities. A key aspect has been the use of a common language among most of the countries in the region which facilitates scientific exchange, information access, and continuing education.

The IAEA has been playing a pivotal role in supporting the development and improvement of NM, including infrastructure, equipment and human resources as part of national and regional technical co-operation projects.

Some weaknesses can also be observed. Universal access to NM procedures is not equal among countries, and even within a country, with greater access to wealthy countries and individuals. Also there is a clear concentration of resources in capitals and large urban communities. The lack of national production of radiopharmaceuticals and radioisotopes as well as other consumables has limited the use of NM techniques in some countries, due to high import costs and limited availability.

One of the key challenges in the region is to identify factors that hinder growth of the specialty and to propose active and open collaboration among regulators and the nuclear medicine community, as well as to promote the coverage of nuclear medicine procedures by health systems. Another limitation is the difficulty to comply with international
standards, in particular due to the lack of harmonization across the region in infrastructure, machinery, quality management, availability of radiotracers and qualified personnel. There are some challenges such as the difficulty to cope with the training needs of the involved multidisciplinary team of professionals namely physicians, medical physicists, technicians/radiographers and radiochemists. Although existent, there are significant differences in the curricula of training programs for physicians and technologists and scarcity of formal training for medical physicists and radiopharmacists. There is a shortage of highly specialized personnel to effectively manage complex equipment such as cyclotrons and hybrid systems (SPECT/CT and PET/CT).

Even though obsolescence of medical equipment has been registered in some countries, that issue has improved in light of equipment replacement programs. However the lack of proper assessment of the impact of introducing novel high-cost health technologies and their sustainability can generate a negative impact in the health cost.

At present there are clear opportunities for the specialty. Demographic and epidemiologic transition in the region generates the need for NM diagnostic and therapeutic procedures in order to provide cost-effective management of prevalent pathologies, in particular cancer and cardiovascular diseases. In addition, economic growth is expected to continue, allowing the investment in state-of-the-art technology and the introduction of novel radionuclide therapies. There are educational opportunities for NM professionals based on ongoing national and international efforts. The development of information and communication technologies will continue to be a key factor for the training and the development of competencies to meet future requirements in human resources.

**CONCLUSIONS**
The future of NM in the Latin American and Caribbean region is promising, with great potential and possibilities. To drive the region towards greater homogeneity with regards to the availability and applications of NM, it is important to identify and acknowledge the factors that play a crucial role in bridging the gaps in the region and in individual countries. We have found from the gathered data and from past experiences of experts and professionals in the field, that some of the most important factors are the awareness of clinicians on the clinical applications of NM techniques in the management of prevalent diseases in the region. The continuous and strong support of international organizations, such as the IAEA, through national and regional projects as well as substantial public-private partnerships and government commitment are fundamental to enabling communities to take advantage of the benefits that NM has to offer. It is essential to build capacity in the field of NM in the region, which means seeking a systematic and integrated approach to develop and improve continuously governmental, organization and individual competences in order to achieve effective, efficient, safe and sustainable utilization of current and future advances in NM.
REFERENCES


FIGURE 1: Gamma cameras per million population
FIGURE 2. Number of PET, PET/CT systems and cyclotrons installed in the region.
FIGURE 3: Nuclear medicine physicians (MD) and technologists (Tech) per gamma camera.
FIGURE 4: Nuclear physicists and radiopharmacists per centre.
FIGURE 5: Types of NM procedures in number/year (from NUMDAB). (Excluding PET)
TABLE 1. Technological resources for nuclear medicine imaging in Latin American and the Caribbean IAEA ARCAL countries

<table>
<thead>
<tr>
<th>Countries</th>
<th>Population (millions)</th>
<th>NM Centres</th>
<th>Gamma cameras</th>
<th>PLANAR</th>
<th>SPECT</th>
<th>HYBRID</th>
<th>TOTAL</th>
<th>PET</th>
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<td>295</td>
<td>48</td>
<td>214</td>
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<td>270</td>
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<td>9.9</td>
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<td>13</td>
<td>28</td>
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<td>42</td>
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<td>1064</td>
<td>87</td>
<td>1231</td>
<td>161</td>
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J Nucl Med.
Published online: July 30, 2015.
Doi: 10.2967/jnumed.114.148932

This article and updated information are available at:
http://jnm.snmjournals.org/content/early/2015/07/29/jnumed.114.148932

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