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Nuclear Techniques in Human Health

prevention, diagnosis, treatment

IAEA

60 Years

Atoms for Peace and Development

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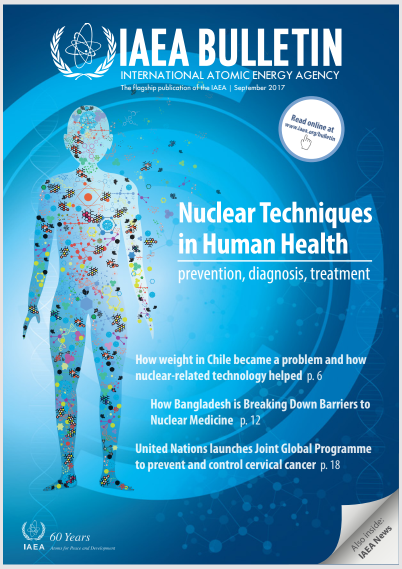

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is produced by the
Office of Public Information
and Communication (OPIC)
International Atomic Energy Agency
PO Box 100, 1400 Vienna, Austria
Phone: (43-1) 2600-21270
Fax: (43-1) 2600-29610
iaeabulletin@iaea.org

Editor: Miklos Gaspar
Managing Editor: Aabha Dixit
Design & Production: Ritu Kenn

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IAEA

The International Atomic Energy Agency's mission is to prevent the spread of nuclear weapons and to help all countries — especially in the developing world — benefit from the peaceful, safe and secure use of nuclear science and technology.

Established as an autonomous organization under the United Nations in 1957, the IAEA is the only organization within the UN system with expertise in nuclear technologies. The IAEA's unique specialist laboratories help transfer knowledge and expertise to IAEA Member States in areas such as human health, food, water, industry and the environment.

The IAEA also serves as the global platform for strengthening nuclear security. The IAEA has established the Nuclear Security Series of international consensus guidance publications on nuclear security. The IAEA's work also focuses on helping to minimize the risk of nuclear and other radioactive material falling into the hands of terrorists and criminals, or of nuclear facilities being subjected to malicious acts.

The IAEA safety standards provide a system of fundamental safety principles and reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from the harmful effects of ionizing radiation. The IAEA safety standards have been developed for all types of nuclear facilities and activities that serve peaceful purposes, as well as for protective actions to reduce existing radiation risks.

The IAEA also verifies through its inspection system that Member States comply with their commitments under the Nuclear Non-Proliferation Treaty and other non-proliferation agreements to use nuclear material and facilities only for peaceful purposes.

The IAEA's work is multi-faceted and engages a wide variety of partners at the national, regional and international levels. IAEA programmes and budgets are set through decisions of its policymaking bodies — the 35-member Board of Governors and the General Conference of all Member States.

The IAEA is headquartered at the Vienna International Centre. Field and liaison offices are located in Geneva, New York, Tokyo and Toronto. The IAEA operates scientific laboratories in Monaco, Seibersdorf and Vienna. In addition, the IAEA supports and provides funding to the Abdus Salam International Centre for Theoretical Physics, in Trieste, Italy.

How nuclear techniques can help improve human health

By Yukiya Amano, Director General, IAEA

Since they were first used in the 1930s, nuclear techniques have made a huge contribution to human well-being and saved tens of millions of lives. Today, they play an increasing role in both the diagnosis and treatment of major non-communicable diseases, including cancer and heart disease.

The Sustainable Development Goals (SDGs) adopted by world leaders in 2015 include a commitment to “ensure healthy lives and promote well-being for all at all ages.” Nuclear science can make a significant contribution to the achievement of this goal. The IAEA is committed to helping its Member States use nuclear science and technology to reduce the number of deaths from non-communicable diseases by one third by 2030, a key SDG target.

Cancer and cardiovascular conditions are the leading causes of death in the world, accounting for 26.5 million of the 56.4 million deaths recorded in 2015. Nuclear techniques make a real difference in these areas.

Medical imaging and radiotherapy are valuable tools for diagnosing, managing and treating cancer. In recent decades, radiation technologies have also become indispensable in addressing cardiovascular conditions, while various isotopic techniques are used to improve nutrition.

Towards equal access

There is, however, a huge discrepancy in access to nuclear techniques. In developed countries, more than half of all cancers are cured, due to early diagnosis and effective treatment. In developing countries, on the other hand, a cancer diagnosis often comes too late for effective treatment.

The IAEA, together with partners including the World Health Organization, is working to change that. We help countries to develop comprehensive cancer control programmes, establish nuclear medicine, radiation oncology and radiology facilities, and support education and training for health professionals — building capacity to make a difference to the lives of millions of people. We also help to ensure the safety of patients, who must receive the right dose of radiation, and of medical and technical staff, who must be protected from harmful exposure.

The 2017 IAEA Scientific Forum showcases the multiple benefits of nuclear techniques for human health. This edition of the IAEA Bulletin highlights the many ways in which they are used. Chile, for example, adapted its national nutrition programme to include the use of nuclear techniques to reduce child obesity (page 6). You will learn about the role of molecular imaging to diagnose dementia (page 10) and how countries like Cambodia (page 8) and Bangladesh (page 12) are addressing cancer care using radiation medicine. The IAEA’s contribution to safety includes quality assurance and dosimetry auditing (page 14) and ensuring the right dose for accurate diagnosis (page 20).

I trust that this edition of the IAEA Bulletin will give readers a better understanding of nuclear techniques in human health and of the role of the IAEA in making this remarkable science accessible to all.

“The IAEA is committed to helping its Member States use nuclear science and technology to reduce the number of deaths from non-communicable diseases by one third by 2030, a key SDG target.”

— Yukiya Amano, Director General, IAEA

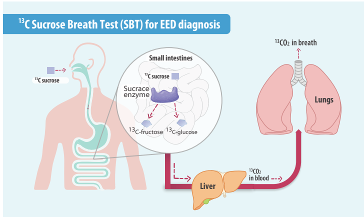
(Photo: C. Brady/IAEA)

(Photo: C. Brady/IAEA)

(Photo: S.Kamishima/IAEA)

Foreword

Preventing Disease through Better Nutrition



Looking Beyond the Visible: New Frontiers in Diagnostic Techniques

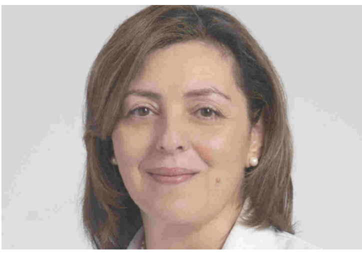
Addressing Implementation Challenges in Countries

Radiotherapy: Saving and Improving Quality of Life of Cancer Patients through New Approaches

Ensuring Quality and Safety

World View

From inside the IAEA



IAEA Updates

Stable isotope techniques used to study link between gut health and child growth

By Jeremy Li

A large proportion of the population in low- and middle-income countries lives in an environment characterized by poor water, sanitation and hygiene conditions, which contribute to growth retardation in children. This is due to adverse modification of intestinal processes, which leads to improper absorption of the nutrients necessary for growth and other functions. This disturbance, originally referred to as environmental enteropathy, is now widely called environmental enteric dysfunction (EED) to reflect its multifaceted manifestations and effects.

A new IAEA-coordinated research project, approved in November 2016, is expected to provide a non-invasive, stable-isotope-based tool for diagnosis of EED in order to understand more clearly how this specific gut-related dysfunction affects the growth and health of children over longer periods of time in low- and middle-income countries. Nine countries from both developed and low-and middle-income settings are participating in this project, as technical experts in the case of developed countries and as research implementers in the case of low- and middle-income countries.

"It is of paramount importance to develop accurate, field-based, non-invasive methods to diagnose the condition," said Victor Owino, a nutrition scientist at the IAEA. Nuclear-based stable isotope techniques offer the advantage that they can be used to assess multiple aspects of EED. (See The Science box.)

The project is studying the effect of EED on child growth and health in specific populations, using a stable isotope technique — the carbon-13 (^{13}C) sucrose breath test. This method has previously been used to assess non-EED-specific intestinal function. The assessment was based on the utilization of naturally ^{13}C-enriched sucrose (from maize).

Since maize and sugarcane are widely consumed in low- and middle-income countries and already contain a lot of ^{13}C sucrose, natural enrichment may not be adequate. Therefore, the project will develop and test the usability of a more highly enriched ^{13}C sucrose breath test.

The carbon-13 sucrose breath test is based on the simple principle that, in the intestine, sucrose is broken down by a brush border enzyme called sucrase into glucose and fructose. When these are oxidized for use by the body, carbon-13 dioxide ($^{13}CO_2$) and water are produced. In abnormal circumstances, as in EED, sucrase enzyme activity and therefore $^{13}CO_2$ production may be reduced. In contrast, in normal circumstances, a strong and early release of $^{13}CO_2$ in the breath following an oral dose of ^{13}C sucrose indicates a healthy gut function. (See the infographic.)

"One way for this method to be more widely employed is to use commercially available highly enriched sucrose with synthetic ^{13}C stable isotopes," said Owino.

Four experts from Australia, the United Kingdom of Great Britain and Northern Ireland (UK) and the United States of America (USA) are working on refining the existing ^{13}C sucrose breath test by using highly enriched ^{13}C sucrose, as described above, and validating the test against gut biopsy to identify gut dysfunction in EED.

First-ever EED study to track effect on longer-term growth using stable isotopes

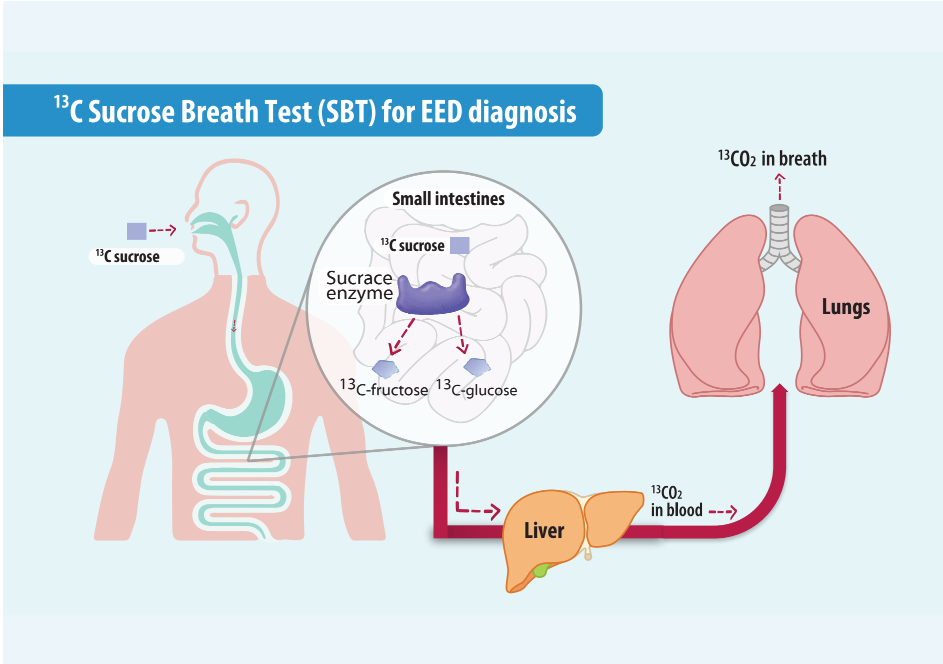
In 2015, the IAEA hosted a technical meeting to consider the current knowledge about EED and discuss interventions to prevent and treat the condition. "One of the conclusions was that more longitudinal studies are needed to better understand the fundamental causes of EED and that there is a need to develop a low-cost and widely applicable test," Owino said.

The new study will, for the first time, measure how EED affects children over longer periods of time. Children will be retested three and six months after the initial tests to determine their growth during this time, Owino said.

Researchers from Bangladesh, India, Jamaica, Kenya, Peru and Zambia are participating in the study. When the testing technique is refined, they will use it to measure EED in children and assess its association with growth over time, Owino added.

In November this year, the IAEA will hold a meeting for stakeholders, technical contract holders and research contract holders from participating countries to harmonize the protocol, develop concrete plans and discuss the logistical details for the longitudinal studies. The experts from Australia, the UK and the USA will present details of the progress of optimization and validation of the ^{13}C sucrose breath test.

IAEA experts have also co-authored two scientific review papers on EED. The papers highlighted the nature of EED, its impact on child nutritional status and health and ways in which stable isotopes may be used to diagnose and manage the condition and its associated health effects. The reviews were published in the world-renowned journals Pediatrics (December 2016) and the Journal of Pediatric Gastroenterology and Nutrition (February 2017) and both were referenced in a comprehensive review by IAEA staff on use of stable isotopes in nutrition assessments, published in the prestigious Proceedings of the Nutrition Society (May 2017).



(Infographic: F. Nassif/IAEA)

THE SCIENCE

What is environmental enteric dysfunction?

Environmental enteric dysfunction (EED) is a modification in intestinal function that seems to present in multiple ways that can be measured separately.

Key among these is that the intestine walls become unusually leaky (porous) and the shape of the tissues lining the intestines is altered, making them less fit to absorb food nutrients and prevent bacterial cells passing through.

Inflammation is another major manifestation in EED and is a natural response by the body to external invasion.

Limited nutrient passage or leakages combined with uncontrolled bacterial cell movement form a complex phenomenon that is thought to limit growth. Growth in children is driven by the growth hormone, which acts like a catalyst to trigger the addition of one block — referred to as a growth plate — to another to ensure linear bone growth from birth to puberty and sometimes beyond. Any process that limits the production or functioning of growth hormone leads to linear growth retardation (stunting). EED-related stress leads to reduced expression of growth hormone receptors in the liver, meaning that growth hormone signalling is inhibited.

The entirety of the microbial population in the digestive tract is called the microbiome. The microbiome is fundamental to human host function, immunity and survival. Stress conditions seen in EED result in microbiome immaturity and replacement of beneficial bacteria with harmful ones. This propagates infection that further adversely affects nutrient utilization and growth.

If the mechanisms underpinning growth retardation in EED are to be fully understood and interventions designed to prevent and treat it, sensitive techniques for diagnosis and classification must be developed for use in the field. Nuclear techniques will be a good addition in this endeavour.

Chile combats obesity in children using nuclear techniques

By Laura Gil

Information gathered using nuclear-related technology helped policymakers in Chile adjust nutrition programmes.
(Photo: A. Gorišek/IAEA)

About 80 million people in Latin America are covered, to one extent or another, by national nutrition programmes. In Chile, one of the reasons why these interventions are more effective today than ever before is nuclear-related technology. This technology enables better diagnosis of malnutrition and provides accurate information to guide and evaluate targeted interventions.

"Whilst nutrition programmes in the early 1990s focused on measuring children's weight, championing weight gain, they failed to take other factors into account," said Ricardo Uauy, Director of the Institute of Nutrition and Food Technology (INTA) at the University of Chile. "They helped to combat undernutrition, but at the same time aggravated, in many cases, overweight and obesity among children."

"Nuclear-related techniques allow us to clarify questions in a way that conventional techniques do not. They are fast, precise and help us see different processes inside the body, defining how much of the weight is lean or fat mass related."

— Ricardo Uauy, Director, Institute of Nutrition and Food Technology, University of Chile

In Latin America, as in other regions, children have become progressively more sedentary, taking less exercise and eating more fat-rich foods. According to the 2017 joint child malnutrition estimates by the United Nations Children's Fund (UNICEF), the World Health Organization (WHO) and the World Bank Group, almost 4 million children under five years of age are overweight in the region, many of them also suffering from a deficiency of essential nutrients such as iron, zinc and vitamin A.

Nuclear techniques can help to determine the human body's uptake from food and utilization of these nutrients.

Gradually, with the help of the IAEA, nutrition scientists like Uauy started assessing children's body composition and energy expenditure — something that nuclear-related techniques enable them to do. They started discovering exactly how a child's weight was divided into fat and fat-free body mass, how the child was taking up and using minerals, and how much of the energy was being used to exercise or was being stored as fat. Accumulating excess body fat and being sedentary — not getting enough exercise — are major risk factors for obesity.

"These tools were adopted by several countries in the region because they were showing us a changing reality," Uauy said. "It became clear that obesity, especially amongst low-income groups, was a problem as important as undernutrition, and that there was a need to change diets and decrease sedentary living."

Childhood obesity increases the risk of diet-related non-communicable diseases, including several forms of cancer, high blood pressure and type II diabetes. In addition, Chilean scientists working at INTA have recently discovered that girls who are obese typically mature earlier and have their first menstrual period at an earlier age, which leads to a higher rate of early pregnancies.

Losing weight

These findings helped policymakers in Chile adjust nutrition programmes, which now provide for higher-quality diets, reduced energy intake from fats and sugar and increased physical activity. As a result, despite rising living standards and sedentary lifestyles, obesity has not increased in the country.

"We've been coming up with diverse and accessible diets, especially for those who cannot afford to eat expensive nutritious food every day," Uauy said. "But we believe it is not enough to inform consumers. We have to make the healthy option the easiest option. This includes formulating and selling the right foods with the right balance between energy and nutrients, and making labels on food items easier to understand by all consumers."

When nutritionists at INTA started collaborating with the IAEA, obesity among pre-school children in a pilot project stood at 10.7% (2001 figures). By 2009, they had managed to reduce the number of calories in school meals and increase children's daily physical activity, bringing the obesity rate among the children involved in the project down to 8.4%.

At the end of 2016, the programme covered three quarters of day-care centres under the jurisdiction of the National Board of Day-Care Centres (JUNJI in Spanish).

Other uses of nuclear-related techniques in nutrition: evaluating muscle health and breastfeeding

The IAEA also supports scientists in the use of nuclear and isotopic techniques to measure human milk intake in breastfed infants, evaluate the bone health of the elderly, track how the body takes in, uses, and retains important nutrients, measure vitamin A reserves and determine how well iron and zinc from local foods and diets are utilized by the body.

For example, the IAEA is currently supporting scientists in Chile in applying stable isotopes and other nuclear-related techniques to studying muscle health and changes in physical activity in the elderly.

"Nuclear-related techniques allow us to do a very exact diagnosis," said Carlos Márquez, nutritionist at INTA. "And diagnoses are important when treating the elderly, since many times it is easier to prevent diseases than to cure them."

The data they are gathering using nuclear-related techniques, Márquez hopes, will help policymakers take measures that will increase elderly people's health and quality of life.

THE SCIENCE

How nuclear-related techniques help measure body fat

To determine precisely the amount of fat in a child's body, for example, scientists use stable isotopes and assess the total body water content. They mark water with deuterium (2H), a stable isotope of hydrogen, and make the child drink it. The water is marked ($2H_2O$) but is non-radioactive and therefore has no adverse health consequences. Scientists take samples of the child's saliva or urine before and after they drink the marked water.

Fat is water-free, by definition. When a boy or girl drinks the marked water, it is evenly distributed in the body's fat-free tissue in a few hours. The marked water that scientists collect and analyse represents the amount of water that the child's lean tissue has absorbed. This helps the scientists determine how much of the child's weight is non-fat — and thus, after calculating the difference, how much fat the children are storing.

To learn more about how stable isotopes work, read: www.iaea.org/topics/childhood-obesity

"Nuclear-related techniques allow us to clarify questions in a way that conventional techniques do not," Uauy said. "They are fast, precise and help us see different processes inside the body, defining how much of the weight is lean or fat mass related."

The IAEA has been helping Chile tackle malnutrition for over 10 years by transferring nuclear and nuclear-related technology, training scientists, organizing expert visits and fellowships and providing materials and equipment.

Doctor's 'crazy' dream comes true with Cambodia's new cancer care facility

By Miklos Gaspar

Sokha Eav standing next to a box containing a gamma camera donated to the National Health Centre by the IAEA. Once Cambodia's new National Cancer Centre opens, the camera will be used for functional images of organs through the detection of radiation emitting radioisotopes injected to the patient.

(Photo: M. Gaspar/IAEA).

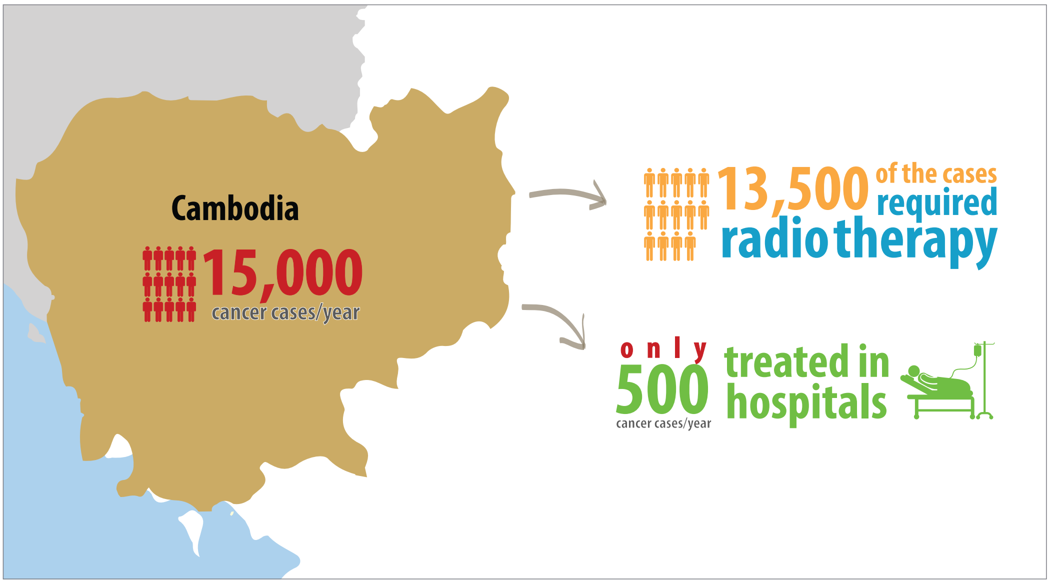
When after medical school, he chose oncology as his field of specialization, many of his colleagues called Sokha Eav crazy. 'Why pick a discipline in which there is no future in this country,' he recalls his friends asking. Fast forward twenty years and Eav, who is the head of the Onco-Hematology Department at Calmette Hospital in central Phnom Penh, is about to realize his dream: the establishment of Cambodia's first ever dedicated cancer care centre. "It has taken me a long time, but I have proven them wrong," he said with a smile.

> "If there were only one thing I could change in cancer care in Cambodia, it would be early diagnosis."
>
> *— Ra Chheang, Director General, Calmette Hospital, Phnom Penh, Cambodia*

The National Cancer Centre at Calmette Hospital in central Phnom Penh is scheduled for inauguration before the end of the year. Much of its equipment, including those donated by the IAEA such as a gamma camera used for body scans and a shielded fume hood to prepare radiopharmaceuticals, are still in boxes or being installed, while its radiotherapy machine — which will only be the second in the country — is on its way from the United States. But construction workers and the staff of the Onco-Hematology Department, which will form the core of the new Centre, are working round the clock to complete the work on schedule.

Cancer is a growing problem in Cambodia, as in much of the developing world. Due to changing life habits brought about by higher living standards and a rapid increase in life expectancy, cancer is becoming one of the main causes of death in the country. While Cambodia does not have a national cancer registry, it is estimated that it has around 15 000 cases of cancer a year out of a population of 15 million. Around 90% of these patients would require some form of radiotherapy, but Cambodia's only radiotherapy machine, at the Khmer-Soviet Friendship Hospital in Phnom Penh, has the capacity to treat only around 500 people annually. Around 1500 patients can afford to pay for treatment in neighbouring countries — leaving the vast majority of cancer sufferers without access to radiotherapy.

Eav's plan will be a major step towards changing that. The Centre will open with one radiotherapy machine, and two more are planned in coming years. Then, by 2025, two Regional Cancer Centres with their own radiotherapy and nuclear medicine facilities will open, one in the north and another in the west of the country, bringing cancer care access to 70% of the population. "That is still not full coverage, but a lot better than where we are today," Eav said.



Cambodia has 15 000 cases of cancer a year. Around 90% of these patients, or 13 500 people, would require some form of radiotherapy, but Cambodia's single radiotherapy machine, has the capacity to treat only around 500 people annually. The country's health authorities are working with the IAEA to increase treatment capacity.
(Infographic: F. Nassif/IAEA)

Cancer diagnosis

Plans also include the installation of a PET-CT (positron emission tomography-computed tomography) machine for medical diagnosis and a cyclotron for the production of radiopharmaceuticals to diagnose and treat cancer. The establishment of a nuclear medicine facility has been a key component of the country's comprehensive approach to cancer care, said Thomas Pascual of the Nuclear Medicine and Diagnostic Imaging Section at the IAEA. "Proper diagnosis is the first step towards treatment," he said.

Getting this far has not been easy, Eav recalls. Initially there was much fear of radiation, even among health officials and hospital administrators. Eav showed them improving cancer statistics from neighbouring countries, and pointed to the IAEA's safety standards and support in protecting the health of workers and patients. Once government officials realized the importance of cancer care, they dedicated resources to building the Centre and purchasing its equipment — a total of US $36 million over the last three years.

What money could not buy, however, was expertise in operating the new equipment, Eav said. This is where support from the IAEA has been invaluable, he added. Half of his core staff, including radiation oncologists, medical physicists, nuclear medicine technologists, radiotherapists as well as a radiopharmacist and a nuclear medicine physician have participated in IAEA fellowships and training in hospitals in the region and in Europe. "They have learned not only technical skills, but also ways of dealing with patients," Eav said. "To create a good ambiance is very important, particularly when dealing with a disease like cancer."

The total value of IAEA technical cooperation projects in Cambodia in cancer care and nuclear medicine has topped €1.2 million over the last few years, said Mykola Kurylchyk, who manages the IAEA's projects in Cambodia. "It was worth every cent," he emphasized. "The results speak for themselves."

Prevention

To really make a difference in cancer survival rates, early diagnosis is key — and it is a major issue for Cambodia, said Ra Chheang, Director General of Calmette Hospital. More than 70% of cancer patients get referred to oncologists only in the final, terminal phase of the disease with little to no chance for effective treatment. In developed countries, this ratio is less than a third. "If there were only one thing I could change in cancer care in Cambodia, it would be early diagnosis," Ra said. Knowing that treatment is available once the new Centre opens will be an incentive for patients to come forward earlier, he added.

International cooperation, including with the IAEA, has been instrumental in the establishment of the new Centre. Once it is up and running, Eav plans to pay back in kind what he has received over the years. "It will be our turn to support other countries and offer fellowships and trainings."

"They used to say I have a wild imagination," Eav says with a grin. "They believe me more now."

Advances in nuclear medicine: Q&A with Satoshi Minoshima on the use of molecular imaging to diagnose dementia

There is no cure for diseases such as Alzheimer's, but accurate diagnosis is important in order to manage patient care. As the 2014 movie Still Alice made clear to a wider public, when accurate assessment of the stage of the disease lags behind, both the patient and caregivers suffer. Enter molecular imaging, which can provide an accurate assessment of the disease even in the presence of other pathologies that are masking symptoms.

To get an idea of the potential and use of molecular imaging in diagnosing brain disorders, Editor Miklos Gaspar sat down with Professor Satoshi Minoshima, Chair of the Department of Radiology and Imaging Sciences at the University of Utah, USA. He is a radiologist specializing in molecular imaging, and has published over 170 peer-reviewed articles.

Minoshima has served as President of the Brain Imaging Council for the Society of Nuclear Medicine and Molecular Imaging (SNMMI) and is currently the SNMMI Vice President and Chair of the Radiological Society of North America (RSNA) Molecular Imaging Committee. He also heads an IAEA coordinated research project on the use of molecular imaging for the diagnosis of dementia, with a focus on the needs of developing countries.

Q: The use of molecular imaging techniques for cardiac diseases, cancer and neurological disorders is well-known. How can these techniques be used when it comes to diagnosing diseases with dementia, such as Alzheimer's?

A: Molecular brain imaging has advanced significantly during the last few decades. Since the 1990s, positron emission tomography (PET) brain imaging with the radiopharmaceutical flurodeoxyglucose (FDG) and brain perfusion single photon emission computed tomography (SPECT) imaging have been critical tools for clinicians to diagnose various brain disorders such as Alzheimer's disease and other forms of dementia. Even though neurodegenerative diseases cannot currently be cured, they often require different and specific approaches for symptomatic treatments, care planning and guidance for caregivers and family members. This means that more accurate differential diagnosis is essential for better patient care.

"These efforts are not only aimed at helping day-to-day patient care, but also provide critical knowledge of the disease process itself that will help improve therapeutic developments."

— Satoshi Minoshima, Chair, Department of Radiology and Imaging Sciences, University of Utah, USA

More recently, amyloid PET imaging has become available in clinical settings in many countries. This technique detects one of the fundamental pathological processes that is associated with Alzheimer's disease.

It is specific to abnormal protein deposits in Alzheimer's disease and provides a more detailed picture than the more general radiotracers used in the past. Its clinical value is currently being evaluated through multi-centre trials.

Other new PET imaging technologies, such as tau imaging and inflammation imaging, are being evaluated by the research community. All these efforts are not only aimed at helping day-to-day patient care, but also provide critical knowledge of the disease process itself that will help improve therapeutic developments.

Q: Alzheimer's and other dementia have obvious symptoms. What additional benefit can molecular imaging bring in their diagnosis and why is it necessary?

A: Not all patients require the use of molecular imaging for their diagnosis. In fact, 85%-90% of patients display common and typical symptoms, allowing clinicians to diagnose them accurately on that basis. Molecular imaging is helpful in complex cases, or when other conditions are also present and it is not immediately clear to which disease the symptoms can be attributed to. Stroke is a common comorbidity. Stroke can influence the brain function on its own, and some of its symptoms can be similar to those caused by neurodegenerative dementia. Molecular imaging allows doctors to distinguish between them.

Q: Two-thirds of the 44 million people suffering from dementia worldwide are in developing countries. These techniques are expensive. Is it realistic for these patients to get access to these diagnostic tools?

A: Although FDG PET and/or brain perfusion SPECT are quite prevalent in many developing countries, molecular imaging is an expensive technology that cannot be applied to all patients suffering from dementia worldwide. The same cost issue does exist in developed countries as well.

For molecular brain imaging to be used most effectively, several professional societies have produced 'appropriate use criteria' for brain PET imaging. By using such criteria, we should be able to use this technology only when it has the biggest impact on patient care and so save precious resources. Also, less expensive tests are being developed that can be applied more widely without requiring expensive imaging. In the future, the use of such technologies should obviate the routine use of more expensive and complex imaging technologies and hopefully guide more effective use of imaging for specific clinical indications and patients with complex clinical presentations.

Q: Could you tell us about the IAEA research projects that you are heading?

A: Dementia, such as Alzheimer's disease, can occur with co-existing conditions such as vascular disease, diabetes and HIV infection. These comorbidities are frequent in developing countries. In order to aid future diagnostic efforts in patients whose conditions are not yet established, there needs to be more analysis of brain imaging findings of patients known to have these comorbidities. Collecting and analyzing such diagnostic image findings is the goal of the IAEA project.

Q: How can the IAEA — including through this research project — help in increasing access to molecular imaging in this field?

A: There are many things the IAEA can help with. Increasing awareness of the technology and educating physicians and patients about how such technology can help clinical management of dementia are key. The IAEA can help make such technology more widely available in developing countries by assessing resources, providing support, and advocating support in Member States.

Breaking down barriers to nuclear medicine in Bangladesh

By Nicole Jawerth

A. Chowdhury came to NINMAS in Dhaka for a diagnostic scan of her kidneys.
(Photo: N. Jawerth/IAEA)

> **"Cost is extremely important for people in Bangladesh. If we didn't provide subsidized care like we do here at NINMAS, many people would not be able to get the care they need."**
> *— Raihan Hussain, Head, National Institute for Nuclear Medicine and Allied Sciences, Bangladesh*

The number of people who can affordably access diagnostic medical care in Bangladesh has increased threefold over the last ten years, as the country has expanded and strengthened its nuclear medical services. Health officials have worked steadily, with the support of the IAEA, to build a nuclear medicine system with well-trained medical staff, advanced imaging tools and a cost-effective source of essential radiopharmaceuticals.

"I came today because this is a very nice facility, but also because it is the most affordable option," said A. Chowdhury following a medical scan of her kidneys at the National Institute for Nuclear Medicine and Allied Sciences (NINMAS) in Dhaka. "Without this kind of public hospital, I don't know how I would have been able to get this help."

NINMAS is one of 15 publicly-funded nuclear medicine centres established around Bangladesh in the last twenty years. It carries out more than 60 000 nuclear medicine procedures (see The Science box) each year in the areas of oncology, cardiology, nephrology and cerebral studies. It also provides therapeutic services for thyroid conditions and eye diseases.

Cost matters

Publicly-funded centres like NINMAS play an important role for Bangladesh's 170 million people, particularly for the quarter of the population who live below the poverty line.

"Cost is extremely important for people in Bangladesh. If we didn't provide subsidized care, many people would not be able to get the care they need," said Raihan Hussain, Head of the Nuclear Cardiology and positron emission tomography (PET)/computed tomography (CT) Division at NINMAS.

A renal scan, like the one Chowdhury received, is a simple procedure in nuclear medicine that allows doctors to evaluate the condition and function of a patient's kidneys, explained Hussain. "In a private practice, this type of procedure costs at least five times as much as it does at NINMAS."

Since its establishment, NINMAS has worked with IAEA experts to procure equipment, receive training and pursue research to further enhance and refine patient care. Its doctors now also teach medical students.

Future plans for NINMAS include the installation of another PET/CT machine and the establishment of a cyclotron facility for producing key radiopharmaceuticals — specialized drugs containing small amounts of radioactive material (see The Science box).

“With the new PET/CT machine, we expect to nearly double the number of patients we can serve with our machines each week,” said Nasreen Sultana, Associate Professor at NINMAS. “The in-house cyclotron will help us to cost-effectively produce radiopharmaceuticals used for PET scans.”

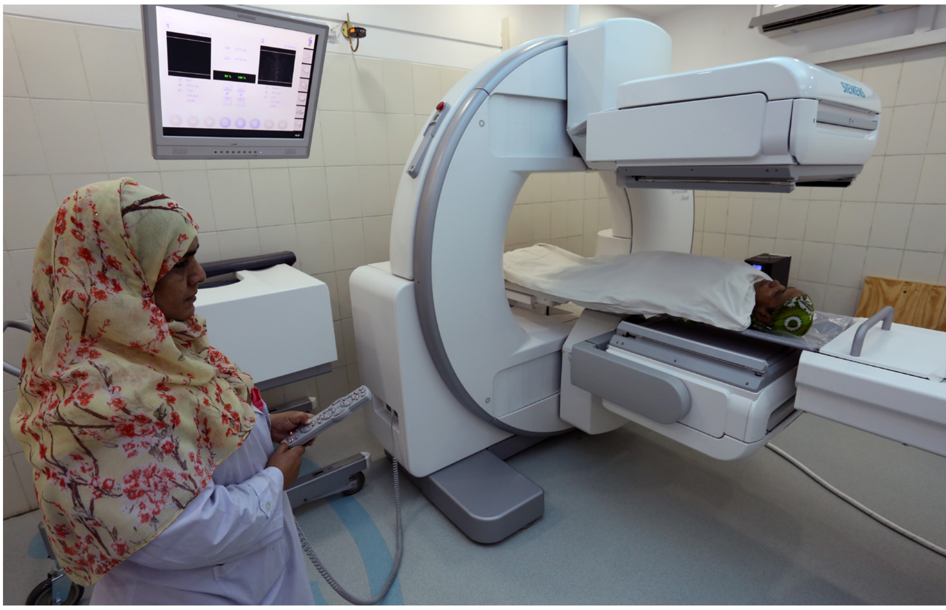
Producing radiopharmaceuticals

The majority of the radiopharmaceuticals used in Bangladesh’s nuclear medicine centres now come from the radioisotope production laboratory housed in the Bangladesh Atomic Energy Commission’s Institute of Nuclear Science and Technology in Savar, just outside of Dhaka. The laboratory relies on a 3-megawatt (MW) research reactor to develop and supply the radiopharmaceuticals used in the over 500 000 procedures performed at nuclear medicine centres every year.

In addition to iodine-131, which is a radioisotope primarily used to diagnose and treat thyroid conditions, the laboratory produces generators of molybdenum-99 (Mo-99)/technetium-99m (Tc-99m). Tc-99m is a radioisotope used in over 80% of nuclear medicine procedures. Each week between 18 to 20 generators — a device used to extract Tc-99m from Mo-99 for use in medicine — are produced at the laboratory, at significantly lower costs than importing already-completed generators. The facilities were established through IAEA technical cooperation projects.

Through its collaboration with the IAEA, the laboratory now also has an ISO-certified clean room facility for producing Tc-99m cold kits, which are used for preparing Tc-99m radiopharmaceuticals for use in diagnostic procedures.

“We also have a plan for a new 20 to 30 MW reactor within the next 10 years. Then we can produce the isotopes locally, and then we may be able to supply to other countries,” said M. Azizul Haque, Head of the Radioisotope Production Division of the Bangladesh Atomic Energy Commission’s Institute of Nuclear Science and Technology.



As the population of Bangladesh grows, more people will need nuclear medicine services like the ones provided at NINMAS.

(Photo: N. Jawerth/IAEA)

THE SCIENCE

What is nuclear medicine?

Nuclear medicine techniques are most often used to evaluate the function of any organ or structure in the body. They provide unique information and offer the potential to identify diseases in the early stages.

The majority of nuclear medicine procedures take place inside the body through specialized drugs called radiopharmaceuticals, which contain radionuclides. When these drugs are taken into the body, they interact with certain tissues or organs. A special detector, such as a gamma camera, outside the body can detect the small amounts of radiation emitted from the organ or tissue. The camera is then able to translate the information into images of the specific tissue or organ. By using radiopharmaceuticals, doctors can get accurate information about the organ or tissue as well as the functioning of organs such as heart, kidneys, liver, among others.

Nuclear medicine is also used for treatment of some diseases and health conditions. Doctors choose small quantities of radiopharmaceuticals that certain body parts absorb more significantly and more effectively than other body parts. This allows them to target specific areas during treatment. The small amounts of radiation in the radiopharmaceuticals then kill off the cells causing the health condition, with minimal effect on other cells in the surrounding area and the rest of the body.

IAEA supports quality assurance through comprehensive clinical and dosimetry audits

Independent quality audits, as part of comprehensive quality assurance programmes, are recognized to be an effective means of verifying the quality of radiation medicine practices. Quality audits include a range of types and levels of review; this article summarizes those provided by the IAEA, including auditing of dose levels delivered in radiation oncology clinics.

The IAEA promotes the need for regular audits in radiation medicine, in the form of peer review missions by experts, and has developed comprehensive guidelines that can support the auditing process in all disciplines, namely radiation therapy, nuclear medicine and diagnostic radiology. It develops guidelines setting out the principles and criteria for good practice of the various components of the clinical service, followed by guidelines for the conducting of the audits.

QUAADRIL

The **Quality Assurance Audit for Diagnostic Radiology Improvement and Learning (QUAADRIL)** methodology, published in 2010, assists hospitals and diagnostic facilities in assessing the effectiveness of their diagnostic radiology services and reviews practices and procedures to better identify shortcomings and suggest ways to improve quality. The results of a QUAADRIL audit include specific recommendations towards:

- improving clinical practice;
- strengthening the quality assurance programme;
- ensuring that patient protection requirements are met;
- developing local (internal or national) clinical audit programmes.

As the purpose of clinical audit is quality improvement, the facility is expected to develop an action plan in response to the QUAADRIL audit recommendations. This action plan can then be used to monitor the facility's response and could include provision for a follow-up review or audit.

QUATRO

The **Quality Assurance Team for Radiation Oncology (QUATRO)** audits help radiotherapy centres attain the best level of practice achievable in their economic circumstances. The operation of QUATRO is based on the use of three experts in the audit teams: a medical physicist, a radiation oncologist and a radiotherapy technologist.

QUATRO experts have a broad experience in the field and receive specialized training in the auditing methodology. The team reviews the entire radiotherapy programme, including the organization, infrastructure, as well as clinical, medical physics and safety aspects of the radiotherapy process. It also includes reviewing the departmental professional competence, with a view for quality improvement. Auditors acknowledge strengths in radiotherapy practices and identify gaps in technology, human resources and procedures, allowing the audited centres to document areas for improvement. As of July 2017, the IAEA has conducted 91 such audits globally.

QUANUM

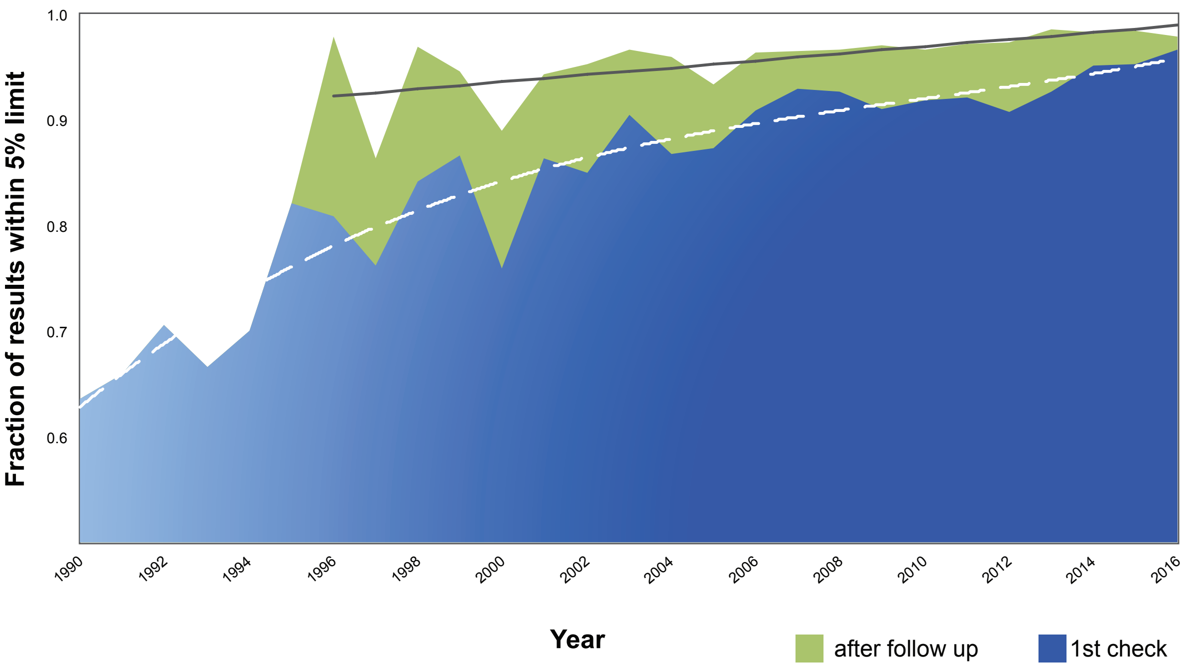
The **Quality Management Audits in Nuclear Medicine Practices (QUANUM)** programme developed by the IAEA in 2009 provides a specific, harmonized and comprehensive evaluation of the quality of the nuclear medicine clinical services provided in Member States. It includes identifying strengths and weaknesses, and supporting facilities to establish priority needs, undertake planning and properly manage resources. The ultimate goal of the audits is to improve clinical practice.

The programme provides nuclear medicine practitioners with a tool to assess their compliance with international standards. Since its introduction in 2009, 53 audit missions to 39 countries have been conducted.

The IAEA regularly organizes training programmes in order to train multidisciplinary teams of auditors to implement a culture of quality among nuclear medicine practices.

Increase in the Accuracy of the Results of IAEA/WHO Postal Dose Audits

The graph shows the fraction of results within the acceptance limit of 5% recorded in the IAEA/WHO postal dose audit service from 1990 to 2016. The blue area shows the results of the first check and the green area the follow-up results after the dosimeter irradiations were repeated in the period mentioned. The graph demonstrates significant improvement during the period.



The IAEA/WHO (World Health Organisation) Dosimetry Audit for Radiotherapy

The IAEA Dosimetry Laboratory offers a dose audit programme, where dosimetry practices are checked regularly, to a high degree of accuracy. It aims to ensure that radiotherapy equipment worldwide is properly calibrated for accurate, reliable and effective cancer treatment.

The IAEA/WHO dosimetry audit programme, which has been in place since 1969, is free to the end-users. Small dose measuring devices called dosimeters are sent to a clinic by post, where a radiation dose is given as it would be to a patient. The dosimeter is then mailed back to the IAEA Dosimetry Laboratory, where it is accurately measured to compare the radiation dose the hospital intended to give with what it actually gave.

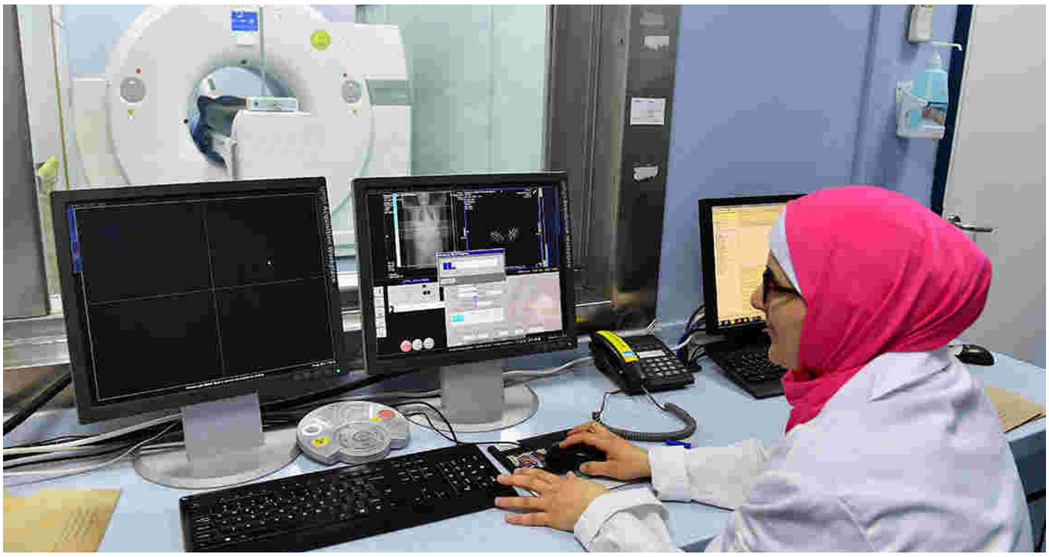
Differences as small as 5% from the intended radiation dose can change the outcome of radiation therapy. Lower doses than intended might jeopardize the effectiveness of treatment, while higher doses could lead to damage of patients' organs. By aiming for high dosage accuracy, a dosimetry audit helps eliminate these risks.

To prevent mistakes in dosimetry from becoming radiation injuries, the Dosimetry Laboratory follows up whenever an audit result is outside acceptance levels. When there is a discrepancy, the clinic is alerted and asked to repeat the test. If the inaccuracy is reproduced in the audit, then the IAEA offers expert support to help the hospital fix the problem effectively.

Records of the dosimetry audit results since the programme's inception show a steady increase in hospitals' abilities to get the dose right, while in 2000, 94 of 391 (24%) audits results revealed a discrepancy, in 2016 only 21 of 623 (3%) results did. Credit for this improvement cannot be attributed solely to improvements in radiation equipment technology. The availability of accurate dosimetry checks made possible through the IAEA/WHO audit has contributed to this increase in accuracy, said Joanna Izewska, Head of the IAEA Dosimetry Laboratory. To date, over 2200 radiotherapy centres in 132 countries have participated in the audits.

Jordan branches out into theranostics — advanced nanomedicine for cancer management

By Aabha Dixit



A medical worker analyses the PET/CT image of a patient at King Hussein Cancer Center.
(Photo: D. Calma/IAEA)

Three words — You Have Cancer — can dramatically change your life. However, medical advances increasingly allow for early diagnosis and make the disease treatable. At the King Hussein Cancer Center (KHCC) in Amman, Jordan, a wide range of nuclear medicine and advanced technologies are used for diagnosis and treatment.

With 4000–5000 new cancer cases diagnosed and treated each year, KHCC is one of the leading hospitals in the Middle East treating cancer patients from the region. A third of its patients come from abroad.

"At KHCC, the objective is to make sure that procedures involving molecular imaging and theranostics are undertaken with utmost attention and care," said Akram N. Al-Ibraheem, Chairman of the hospital's Nuclear Medicine Department. Theranostic technologies are nano-based procedures to improve imaging and therapy for cancer care, and offer cutting-edge biomedical health care products and services. "Benefits are many, but if proper procedures are not followed, there are significant risks to patient safety," he cautioned.

"Theranostic technologies include nano-based procedures to improve imaging and therapy for cancer care, and offer cutting-edge biomedical health care products and services."

— Akram N. Al-Ibraheem, Chairman, Nuclear Medicine Department, King Hussein Cancer Center, Jordan

Techniques and technologies of radiation medicine — which include the disciplines of nuclear medicine, diagnostic radiology and radiotherapy — offer effective means to combat cancer. They offer unparalleled benefits, enabling insights into physiological function, biological processes and morphology that provide more specific information about organ function and disease.

Theranostic techniques pinpoint cancer cells

Theranostics in particular can change the entire health care programme for cancer treatment. It integrates molecular diagnostic and therapeutic capabilities into a single platform, providing an effective method for detecting and characterizing disease at cellular and molecular levels in order to tailor a targeted therapy. This approach is not only capable of diagnosing the disease, but also predicts drug delivery and can be used to monitor response to therapy.

"In the era of theranostics, we will utilize the molecular signature of the disease by studying the changes at the level of protein and DNA of the patient's individual diseased cells. This will eventually result in delivering the right therapy for the patients," Al-Ibraheem said. Molecular signatures are sets of genes, proteins and genetic variants that can be used as markers to assess gene characteristics.

Theranostics targets a specific cancer tumour or diseased body area. A nanoparticle introduces the therapeutic drug into the body to travel to the specific tumour spot to attack the cancer cells directly. The impact to the surrounding body areas is limited.

The nuclear medicine modality of positron emission tomography combined with computed tomography (PET/CT) is used for molecular imaging and theranostics. The uniqueness of theranostics is that the same nanoparticle or molecule can be used for imaging the tumour or treating it, depending on the particular isotope used for labelling. This eliminates the uncertainties inherent when using different compounds for diagnosis and therapy.

The KHCC introduced theranostics in June 2015, in particular for patients with neuroendocrine tumours, which are abnormal tissue growth that mainly occur in the intestine, pancreas and lungs. Most patients who received this treatment at KHCC have shown significant improvement in their quality of life with prolonged survival. Some have been documented to have partial response to the theranostics treatment as demonstrated by imaging modalities and biomarkers, Dr Al-Ibraheem added.

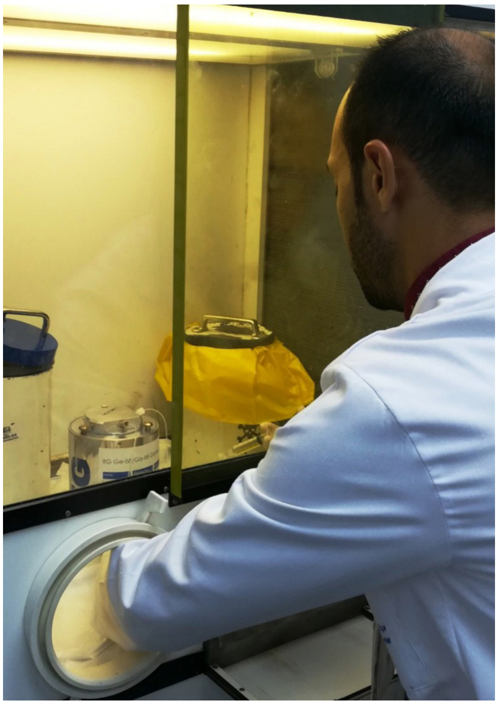
Spread the word

Raising awareness of how nuclear medicine can help in cancer treatment is not easy in countries where 'cancer' remains a taboo word. The KHCC has a public awareness campaign to promote the motto 'right diagnosis is half way to the right treatment', Al-Ibraheem said. It hosts workshops and reaches out to local civic bodies as part of its efforts to build public awareness on the importance of early detection and prevention and to raise funds to help support the KHCC.

Tackling cultural and social stereotypes about cancer and encouraging people to get tested go hand-in-hand, he said. Recovering patients and their families also play an influential role in spreading the word on how 'new technology' helps to combat cancer, he explained.

Precise training in nuclear medicine and diagnosis

Having advanced medical equipment on its own is not enough: equally important is providing the necessary training to medical personnel. As part of its efforts to ensure high-quality care, the KHCC has a dedicated training centre that offers education and training on nuclear medicine and diagnosis among other disciplines in cancer care.



A nuclear medicine technician prepares a PET/CT radiopharmaceutical for a patient with a neuroendocrine tumour.

(Photo: King Hussein Cancer Center, Jordan)

The centre offers medical and non-medical courses to both KHCC staff and health care professionals from across the country and the region. It includes a fully comprehensive oncology nursing education programme, which provides detailed guidelines and procedures on the safe use of nuclear medicine and diagnostic equipment. To ensure maximal benefits and minimal risks, it is essential that the nuclear applications in medicine rely on guaranteed attention to all aspects of radiation safety, adequate dosimetry and quality assurance procedures.

IAEA support

Through its technical cooperation programme, the IAEA has helped the KHCC to establish training programmes in nuclear medicine and diagnosis. Training provided to nuclear medicine physicians, radiologists, radiotherapists, and medical physicists has contributed to the establishment of a high calibre staff on-call for cancer care, Al-Ibraheem said. This training has been supported through expertise, fellowships, training courses and an exchange of information such as in radiation oncology and medical physics.

United Nations agencies launch joint global programme to prevent and control cervical cancer

By Aabha Dixit

Brachytherapy forms an important part of radiotherapy treatment in cervical cancer.
(Photo: D. Calma/IAEA)

In 2012, more than 260 000 women worldwide died of cervical cancer — the equivalent of one woman dying every two minutes. Over 90% of these deaths occurred in developing countries. In response to this health crisis of global proportions, seven United Nations agencies last year launched the five-year United Nations Joint Global Programme on Cervical Cancer Prevention and Control.

Earlier this year, expert teams reviewed the cervical cancer prevention and control programmes of Mongolia, Morocco and Myanmar, the first three pilot countries in the project. The recommendations made for these countries included specific efforts to improve cervical cancer prevention, screening, early diagnosis and access to treatment, including radiotherapy and palliative care. Reviews of three other countries — Bolivia, Kyrgyzstan and Tanzania — will follow later this year.

"The choice of cancer of the cervix as the focus for this global effort reflects the significant economic and human dimensions surrounding a cancer that occurs in women at the height of their productive years," said May Abdel-Wahab, Director of the IAEA Division of Human Health. The goal of the project is to achieve a 25% reduction in cervical cancer mortality by 2025 in participating countries, by reducing the number of cervical cancer cases and improving survival rates, she added.

> **"The goal of the project is to achieve a 25% reduction in cervical cancer mortality by 2025 in participating countries, by reducing the number of cervical cancer cases and improving survival rates."**
>
> *— May Abdel-Wahab, Director, Division of Human Health, IAEA*

Imparting knowledge and training are core components of support to improve the quality and safety of radiotherapy. For instance, in Myanmar, the United Nations team's recommendations identified the need for more training for radiation oncologists, medical physicists and radiotherapy technicians at public radiotherapy centres, supporting skills upgrade and training in the safe and efficient use of radiotherapy machines, said Rajiv Prasad, a radiation oncologist at the IAEA who was part of the UN team who visited the country.

The importance of developing national treatment guidelines for cervical cancer and establishing a robust referral mechanism for cervical cancer patients were identified during the visit. "Developing a pool of trained staff to support radiotherapy services is critical to cancer assessment and treatment," Prasad said.

The Joint Programme's efforts also include the development of comprehensive national cervical cancer control plans to increase the capacity of health systems to diagnose and treat cervical cancer, and provide palliative care.

"The IAEA has a significant role in this initiative, as radiation therapy — both as external beam radiation therapy and brachytherapy — is an important element in the treatment of cervical cancer. Over 70% of women with cervical cancer need radiation therapy for cure or palliation," said Abdel-Wahab, adding that radiotherapy improves control of the cancer locally in the pelvis and leads to greater survival rates.

Cervical cancer can also potentially be prevented through vaccination against human papilloma virus (HPV) and early detection through screening. It is estimated that a cervical cancer-specific vaccination for girls today would prevent around 600 000 of them developing cervical cancer later in life — and 400 000 from dying from this preventable disease. In this context, the importance of immunizing all adolescent girls against HPV and the critical need for effective treatment of pre-cancerous lesions for all women are key goals of the Programme.

Enhancing cancer care for women

International experts will work with the six selected low-and middle-income countries to mobilize the necessary resources to widen awareness through domestic, bilateral and multilateral channels and reduce morbidity and mortality from this disease. The goal is to ensure that at the end of five years, each participating country has in place a functioning and sustainable high-quality national cervical cancer control programme.

Cervical cancer is a potentially curable cancer that in too many cases is discovered too late to prevent morbidity or death, said Abdel-Wahab. Proactive actions can therefore significantly reduce cervical cancer deaths.

The IAEA's unique mandate and role in radiation medicine, encompassing nuclear medicine, diagnostic radiology and radiotherapy, is an important factor in attaining the objectives of this global effort against cervical cancer.

It is important to have well-structured national capabilities in the areas of radiation medicine, explained Prasad. Capacities vary widely and access to quality radiotherapy, for example, is severely limited in low-and middle-income countries, which make up 85% of the global population yet only have about one third of the world's radiotherapy facilities, he added.

Nicholas Banatvala, Senior Advisor at the World Health Organization and at the United Nations Interagency Task Force on noncommunicable diseases (NCDs) described the role of the Interagency Task Force in facilitating collaboration of United Nations agencies for a more comprehensive solution to address the challenge of NCDs. "On cervical cancer, our goal is to work with global and national partners to ensure that each participating country has a functioning and sustainable, high-quality national cervical cancer control programme in place at the end of five years," he said.

The IAEA and six other United Nations agencies are part of the UN Interagency Task Force on NCDs working to prevent and control cervical cancer: the World Health Organization, the International Agency for Research on Cancer, the Joint United Nations Programme on HIV/AIDS, the United Nations Population Fund, the United Nations International Children's Emergency Fund (UNICEF) and United Nations Women.

The international expert team of the United Nations Joint Global Programme visits Mongolia to provide guidance and recommendations to help enhance the country's cervical cancer programme.

(Photo: World Health Organization Country Office, Mongolia)

The right dose for accurate diagnosis: tracking patient radiation doses and using diagnostic reference levels

By Aabha Dixit

"With the patient being the focus for any medical diagnosis, dose evaluation and diagnostic reference levels for patients are recognized as important tools for optimization of patient radiation protection."

— Ehsan Samei, Professor of Radiology and Medical Physics, Duke University Hospital, United States

Evaluating radiation dose levels during diagnostic radiological procedures and using this data to improve the quality of diagnostic exams and patient safety are vital when carrying out radiation therapy and treatment.

Approximately 3.6 billion diagnostic radiological procedures are performed around the world each year. Although the use of ionizing radiation for medical purposes offers many benefits, it can also increase the risk of cancer later in life. Where more radiation is used than is necessary to provide a clinical diagnosis, the patient can incur an increased risk but no additional benefit. Ideally, medical imaging procedures should be performed only when well justified and should use the lowest possible amount of radiation necessary to provide an image quality that is sufficient for diagnosing disease or injury.

"With the patient being the focus for any medical diagnosis, dose evaluation and diagnostic reference levels for patients are recognized as important tools for optimization of patient radiation protection," said Ehsan Samei, Professor of Radiology and Medical Physics at Duke University Hospital in the United States.

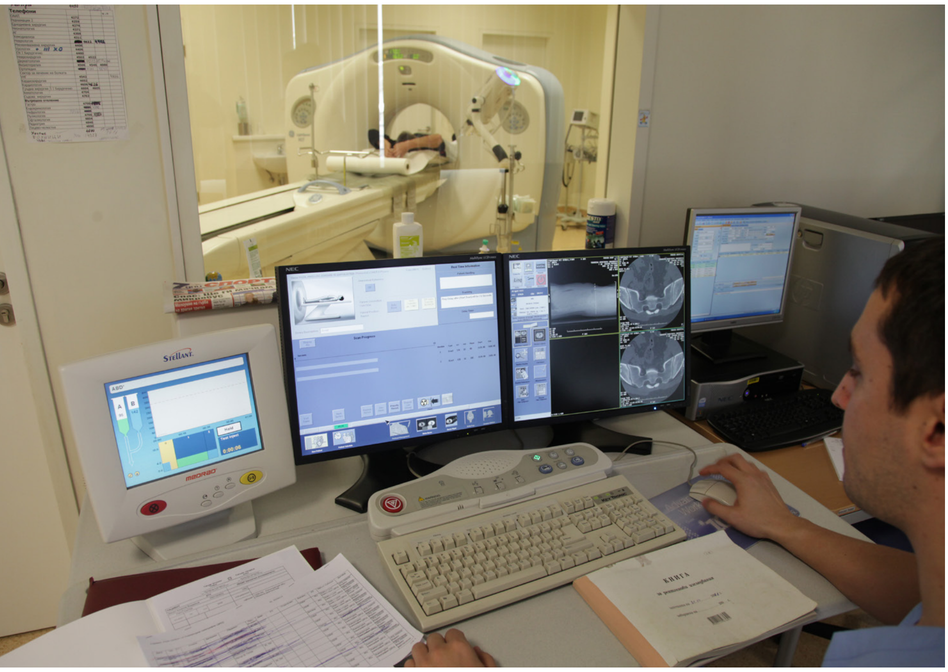
"In some cases the patient receives an incorrect dose, which can jeopardize the quality of diagnosis. The doses used in radiation procedures therefore need to be regularly evaluated to ensure the patients' safety and the quality of medical images," he added.

What are diagnostic reference levels?

Diagnostic reference levels serve as a practical tool that allows health professionals to compare diagnostic imaging procedures across a country. They apply for a specific patient group, such as adults or children of different ages or weight, and relate to specific types of medical examinations such as X-rays, computed tomography or image-guided interventional procedures.

To ensure effective and accurate imaging, each hospital should compare local doses to the nationally- or regionally-set diagnostic reference levels, Samei said. "To achieve this goal, we need to have purpose-specific diagnostic reference levels." Diagnostic reference levels should relate to the purpose of the imaging. For example, cancer and cardiovascular imaging may have different diagnostic reference levels. The aim is to have a universally-agreed methodology for setting and using diagnostic reference levels, he added.

The practical implementation of diagnostic reference levels is a complex task, requiring thorough knowledge of the medical technology and technical skills to perform patient dosimetry and analyse image quality. It requires effective coordination between the health authority, relevant professional bodies, the nuclear regulatory body, and medical facilities motivated to participate in data collection, said Peter Johnston, Director of the IAEA Division of Radiation, Transport and Waste Safety.



Analysis of radiation doses to patients during diagnostic radiological procedures is key to improving patient safety.
(Photo: Tokuda Hospital, Bulgaria)

A comprehensive regulatory and legal framework, a sustained awareness-building programme and effective evaluation tools to implement internationally-agreed safety standards on radiation protection for patients are also vital, he added.

Why track radiation dose data?

Accurate and regular recording, reporting and analysis of patient radiation doses in medical centres can help improve practice and reduce doses without loss of diagnostic quality. This information can be used to establish diagnostic reference levels at the national or regional level. Tracking exposure information for each patient can also help to prevent unnecessary exposure.

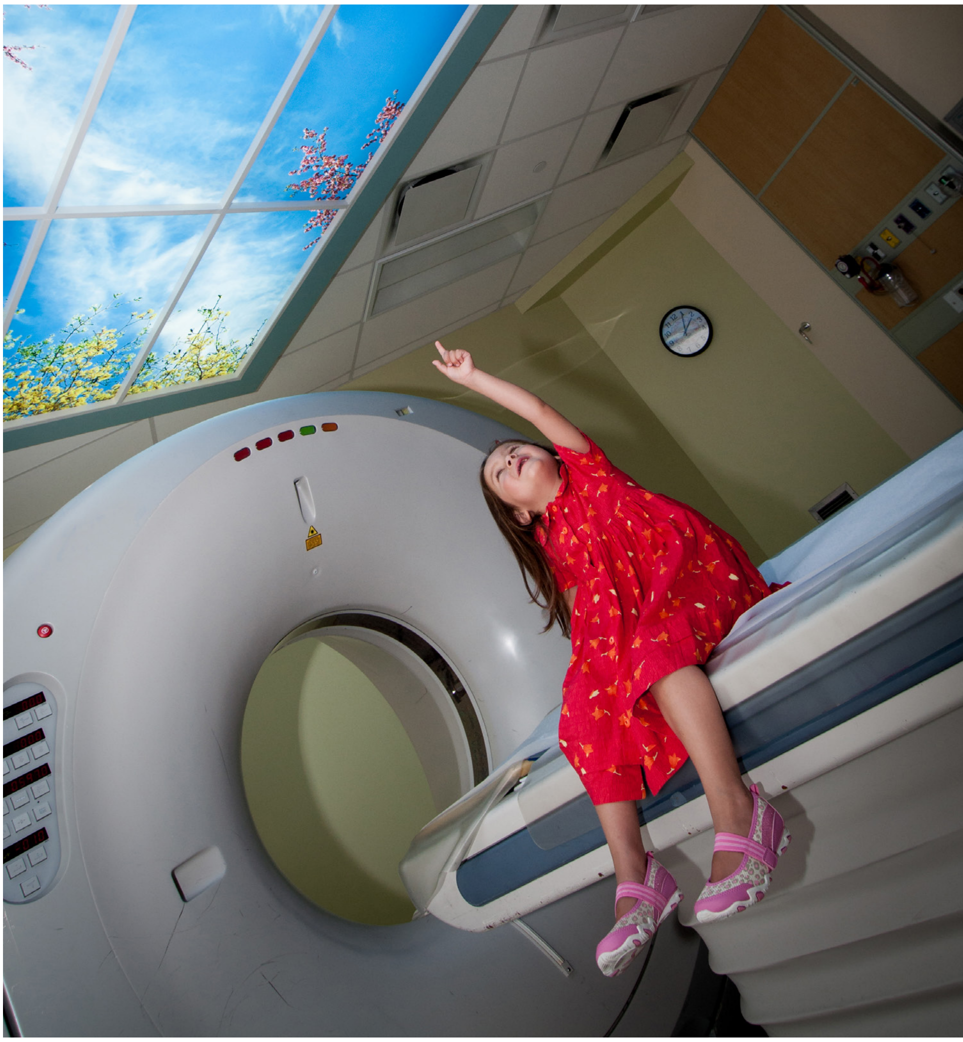
Medical staff have to follow strict rules and are trained to ensure the safety of those patients who are given radioisotopes for diagnostic or therapeutic purposes.

Patients sometimes move from one imaging facility to another. New tests are done, involving duplication of radiation examinations, said Simone Kodlulovich, President of the Latin American Medical Physics Association (ALFIM). "What is lacking in many countries is a data system that tracks doses. We need to be more consistent and follow established guidelines consistently."

Another area that needs special attention by health professionals when performing exams is imaging of children, whose sensitivity to radiation is higher. Monitoring of doses to children in medical facilities helps to improve clinical outcomes and reduce risks. Without proper and specialized guidance, the advanced technology has the potential to significantly increase patients' exposure to ionizing radiation, said Kodlulovich.

Cooperate, coordinate to prevent overuse

Fast-moving technological developments in medical imaging are providing new opportunities to automatically track and benchmark patient doses. Early evidence in some countries with more advanced electronic systems is very promising, said Samei. Furthermore, closer involvement of medical equipment manufacturers and developers of specialized dose tracking software is needed to establish proper standards as well as to coordinate further improvements.



Children are more sensitive to radiation doses than adults.
(Photo: McMaster Children's Hospital, Canada)

What do I need to know?

Two general principles of radiation protection — justification and optimization — apply to the exposure of patients undergoing medical radiological procedures.

Justification of medical exposure entails weighing the diagnostic or therapeutic benefits of exposure against the potential for harm, taking into account the benefits and risks of available alternative techniques that do not involve ionizing radiation exposure.

Optimization of protection and safety in diagnostic and interventional medical exposure entails limiting the exposure of patients to the minimum necessary to achieve the required diagnostic or interventional objective.

Dose limits do not apply to medical exposure, as they could limit the benefits for the patient.

Albania enhances radiotherapy treatment for cancer patients with IAEA support

By Jeremy Li

Medical staff preparing for a radiotherapy treatment session with the first linac machine at the radiotherapy department of the University Hospital Centre "Mother Teresa", in Tirana.

(Photo: University Hospital Centre "Mother Teresa", Albania)

The lack of proper cancer care equipment and facilities in developing countries means that many patients are left untreated. Radiation therapy machines are an essential part of effective cancer treatment, but they are expensive to acquire and maintain. With the help of the IAEA, Albania has been able to provide radiotherapy for its cancer patients and is now adding to its fleet another efficient, state-of-the-art linear accelerator (linac).

In Albania, cancer continues to be a major public health problem. According to the country's Ministry of Health, cancer is the second greatest cause of death (16.6%), after cardiovascular disease. Every year, there are about 7140 new cancer cases reported, of which 3900 need radiotherapy as part of their treatment. With a population of 3.3 million, Albania currently has five radiotherapy machines: a cobalt-60 teletherapy machine and a linac at the radiotherapy department of the University Hospital Centre "Mother Teresa" in the capital Tirana, one linac in the neurosurgery department of the same hospital and two linacs in private practice.

The Austrian Government helped Albania to acquire the first linac machine for the radiotherapy department of the University Hospital Centre in 2015. The IAEA assisted with the commissioning of the machine and helped to train the medical staff in machine handling and radiation safety.

In addition, the IAEA is supporting Albania with the installation of another linac machine at the University Hospital Centre later in 2017. The IAEA's support includes the provision of quality assurance equipment that measures the radiation levels used and helps to make sure that the machine is properly calibrated and the patients are receiving the prescribed doses, said Brendan Healy, a radiotherapy medical physicist at the IAEA.

The first linac machine at the radiotherapy department of the University Hospital Centre "Mother Teresa" in Tirana.

(Photo: University Hospital Centre "Mother Teresa", Albania)

Integrating cobalt-60 machines and linear accelerators for cancer treatment

Linacs and cobalt-60 (Co-60) machines are two of the most commonly used pieces of equipment for external beam radiation therapy, a procedure in which high-energy beams are used to kill tumour cells. Both Co-60 machines and linacs have been used for cancer treatment since the 1950s.

When it comes to the options for radiotherapy there is no standard answer. An equipment choice should be the result of careful analysis that considers not just the technological characteristics of the machines but also the local infrastructure, the evaluation of maintenance requirements, affordability and the availability of well-trained personnel, according to May Abdel-Wahab, the Director of the Division of Human Health at the IAEA.

"We want our Member States to be fully aware about the different infrastructure needs for the effective utilization of radiotherapy equipment before purchasing a particular machine," she said.

Keeping it safe: training and fellowship

Due to the complexity of the radiotherapy process, radiation oncologists, medical physicists and radiation therapists — the three types of medical professionals instrumental in carrying out the treatment — must undergo rigorous training to ensure a safe and successful procedure for the patients and safety for themselves.

After a new radiotherapy machine is delivered to a country and about to begin operation in clinical settings, the IAEA supports the recipients in three ways: it arranges for machine-specific training by the manufacturer; it supports medical professionals in taking up fellowships in countries that already have similar equipment in operation; and it sends experts to verify the commissioning process of the machine, in the interests of both effectiveness and safety.

Cancer is a battle that can only be won if everyone works together

By Kim Simplis Barrow, First Lady of Belize

As a cancer survivor and Belize's Special Envoy for Women and Children, one of my main goals is to reduce the burden of cancer and give hope to those negatively affected by this disease in its many manifestations.

Even though my country is a small nation with limited resources, I firmly know that, collectively, we can do more to ensure that persons everywhere have access to effective, affordable and comprehensive cancer prevention and treatment services. My knowledge comes from successful initiatives taken in my role as Special Envoy for Women and Children: the construction of the Inspiration Center, which provides facilities for children with disabilities, and a state-of-the-art paediatric and neonatal intensive care unit at Belize's national referral hospital — the Karl Heusner Memorial Hospital.

Reflecting on my own experience, I am acutely aware of the importance of early detection of cancer, access to information and proper treatment services. I am also fully committed to the level of engagement necessary to ensure that cancer control initiatives are integrated into Belize's health and development agendas.

According to the Pan American Health Organization, cancer is the leading cause of death in our region and, based on our current path, the projection is that the number of cancer deaths will almost double by 2030.

Belize has a population of a little over 370 000, with over half our citizens living in poverty. Statistics from the Ministry of Health reveal that cancer continues to be the third-highest cause of death in the country. Belize, with other low and middle income countries, has come to understand the magnitude of the cancer problem and the devastating effects it has on a country's economy and overall development.

As a breast cancer survivor, I was among the minority of persons in my country who were able to travel abroad for oncology care. I was blessed to have access to excellent medical care and support throughout my journey. Too many people in Latin America and the Caribbean experience late diagnosis and treatment, which can be attributed to lack of oncology personnel and critical oncology treatment in our countries. With high poverty levels in many families, cancer care is quite often inaccessible or made possible only through community intervention. These factors impact the lives of families affected by cancer and often result in low survival rates.

Chemotherapy services have recently become available to our citizens through the generosity of a Belizean oncologist and his dedicated team; however, management of complications of cancer treatment and of the physiological and psychosocial issues affecting a patient's survival is less than optimal within the wider health system. These issues must be addressed if we are to provide equitable, accessible, affordable and quality health-care services.

I am also spearheading the establishment of a cancer centre to provide comprehensive oncology services and, ultimately, remove the need for and expense of travelling abroad for cancer services. Given my experience in establishing centres of excellence, I am seeking to collaborate with organizations like the IAEA and donor agencies in the training of oncology physicians, nurses and other personnel needed for a comprehensive cancer care programme.

We recognize the importance of partnerships, and we are grateful for the IAEA's expert mission to Belize in December 2016, during which a thorough assessment of our country's cancer care response was conducted. Preparations are under way for a second assessment by the IAEA, to determine the best geographical site for the establishment of a cancer centre for the people of Belize. Fighting cancer is a battle that can only be won if everyone works together. Support from the IAEA, the World Health Organization and other global agencies is critical to controlling cancer in developing countries like Belize.

IAEA support in human health

By May Abdel-Wahab, Director, IAEA Division of Human Health

The field of medicine has seen unique advances over the last century — among them is the discovery of radiation and radionuclides for use in medicine. This has led to more diversified and effective prevention, diagnostic and treatment options for many health conditions. Diseases like cancer can now be diagnosed earlier and treated more effectively with the help of nuclear techniques, thus giving more patients a fighting chance and, for many, a significant chance for a cure.

Nevertheless, the increasing number of people each year affected by non-communicable diseases (NCDs), such as cancer and neurological and cardiovascular disorders, places great pressure on healthcare systems and leaders worldwide to provide effective solutions, even though the resources to diagnose and treat these conditions may be scarce, or often not available. The IAEA programme in human health contributes to the many ongoing global efforts to address these health challenges and enhance capabilities in Member States.

The Human Health Programme provides a comprehensive approach to the prevention, diagnosis and treatment of NCDs in four main areas of support: nutrition; diagnosis and follow-up; radiation oncology and radiotherapy; and quality assurance. Together, they contribute to the achievement of Goal 3 of the United Nations Sustainable Development Goals (SDGs) — good health and well-being.

Good nutrition is the foundation of human well-being. The IAEA supports the SDGs through the application of nuclear techniques, in particular using stable isotopes for disease prevention and life in good health. The IAEA enhances countries' capabilities and helps them combat malnutrition in all its forms and promote better health throughout life by encouraging the use of accurate nuclear techniques (including stable isotopes) to design and evaluate interventions, with a focus on infant and young child feeding; maternal and adolescent nutrition; high-quality diets; prevention and control of NCDs; and healthy ageing.

Recognizing that the resources available for health vary significantly between and across regions, the IAEA develops strategies to support Member States optimize their resources without compromising the quality of the services provided. This requires careful selection of treatment options which, in turn, relies on a clear understanding of the disease and the stage it has reached. Nuclear medicine and diagnostic imaging play a key role in the diagnosis and management of NCDs. Imaging permits screening of populations at risk, early and accurate diagnosis and careful prognostic assessment — all of these leading to appropriate therapeutic decisions and monitoring of treatment. In addition, the IAEA provides technical expertise in radiotherapy, which involves the use of ionizing radiation in the treatment of patients with cancer as well as some benign conditions.

Training professionals

The lack of qualified professionals is one of the main obstacles preventing the sorely needed modernization and expansion of radiotherapy services in the developing world. Adequate human resource planning is needed to accompany government investment in equipment. Supporting initial education and training of radiotherapy professionals, such as medical physicists, radiation therapy technologists and radiation oncologists, as well as continuing education and training of previously trained professionals to update or expand their knowledge and skills is a priority.

The IAEA enhances Member States' capabilities in the design of sound policies for radiotherapy, cancer treatment and other applications of radiation in human health. Other research activities include the applications of radiation biology, mainly in the areas of clinical biological dosimetry, tissue sterilization for tissue banking, and instructive surfaces and scaffolds in tissue engineering.

It is estimated that 10 million people each day undergo diagnostic, therapeutic or interventional procedures involving medical radiation. While the majority of these procedures are performed safely and appropriately, there are situations throughout the world where radiation protection and safety are either lacking or deficient, creating a risk to patient health. For this reason, ensuring the safe use of radiation procedures is an integral part of the IAEA's work and mandate.

The methods used for imaging and treatment require accurate dosimetry and complex quality assurance procedures to ensure that appropriate clinical outcomes can be achieved without compromising the safety of the patient. The IAEA develops internationally harmonized codes of practice and guidelines for dosimetry and quality assurance, as well as recommendations for best practices, and provides guidance to Member States for their implementation. It also maintains a dosimetry laboratory, which plays a key role in establishing and disseminating best practices for the safe, secure and effective use of radiation in the diagnosis and treatment of cancer.

For more information, visit www.IAEA.org and the Human Health Campus website (https://humanhealth.iaea.org/hhw).

Benin farmers triple yields and improve livelihoods thanks to isotopic technique

Félix Kouelo Alladassi, Assistant Professor in Soil and Water Conservation at the University of Abomey-Calavi, preparing soybean plants for an experiment using isotopic techniques.
(Photo: M. Gaspar/IAEA)

Soybean farmer Leonard Djegui never had the chance to go to school, but he has learned two facts about nuclear science in recent years: atoms make up the soil and they have helped triple his income, allowing him to build a new house and send his children to university.

Djegui is not alone: around 14 000 farmers in central and northern Benin have achieved significant yield increases for both maize and legume crops such as soybean — providing more food for their families and much higher incomes than they could even dream of a few years ago.

"I did not go to school, but I do understand that science is important," Djegui said, proudly showing his new house, made of bricks, replacing his previous mud hut. "It allows my maize and soya to grow taller and provides for a much richer harvest."

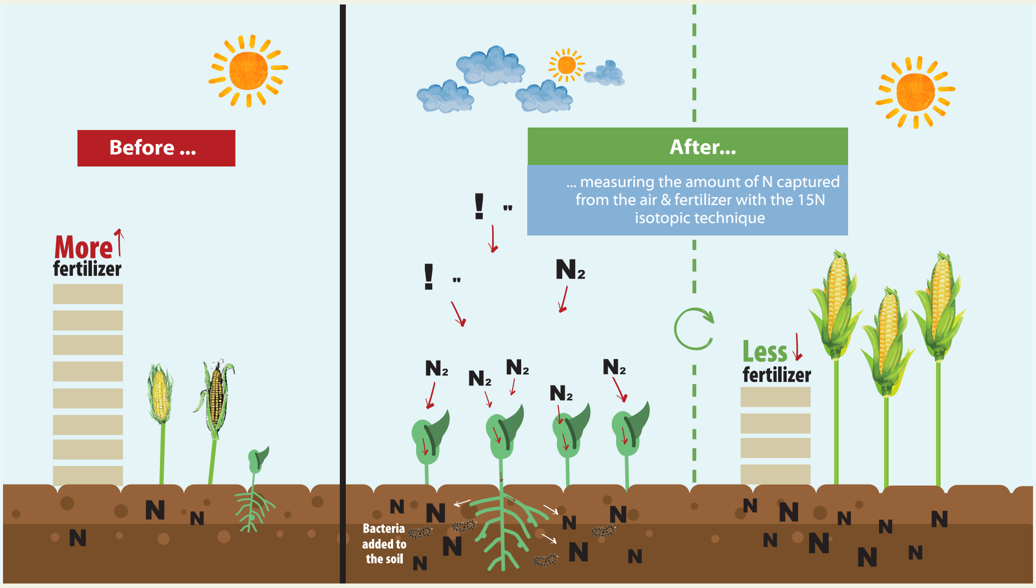
The secret: the use of isotopic and nuclear-derived techniques to measure and properly increase the amount of nitrogen — necessary for plant growth — the crops take up (see The Science box). Legumes such as soybean and peanuts are able to take up nitrogen from the air, which they then deposit in the soil, making it more fertile for the maize crop that farmers plant the following season, explained Pascal Houngnandan, Vice President of the National University of Agriculture and Director of Soil Microbiology at the University of Abomey-Calavi, the country's main research institution, just outside the capital Cotonou. This intercropping of maize and legumes results in increased yields of both crops. Depending on the soil type, it also means little or no commercial fertilizer is required, saving farmers that additional expense.

The IAEA, in cooperation with the Food and Agriculture Organization of the United Nations (FAO), has supported the project by providing expert advice and helping Houngnandan and his team interpret the data. The IAEA, through its technical cooperation programme, has also provided much needed equipment and training that allow the researchers not only to conduct the experiments, but also to produce the bacteria required for the legumes to take up even more nitrogen from the air.

Scientists in 70 countries benefit from such assistance, including support to customize the method to their particular crops and soil types, said Joseph Adu-Gyamfi, soil fertility management specialist at the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture.

Mixing seeds and bacteria

In June, at the beginning of the planting season, Djegui and his neighbours were busy mixing the bacteria received from the lab with the soybean seeds that were to be planted in the following weeks. Meanwhile, other workers from this village of 1000 were clearing weeds from surrounding land that used to lay bare, so that more soybean can be grown.



The nitorgen-15 isotopic techique enables scientists to measure the amount of nitrogen legumes conver from the air and deposit in the soil, thereby improving soil fertility for other crops - in this case maize. Using bacteria, they can also enhance the legumes' ability to fix more nitrogen. (Infographic: F. Nassif/IAEA)

Albert Ahotondji, one of Djegui's neighbours, is now growing soybean on six hectares of his land, up from two hectares two years ago. Previously he did not have the cash to buy seeds and fertilizer for all of his land, and was forced to leave some of it unused. He now has enough cash to till his entire land and can also put money aside for when his children go to university. "I will be able to afford to rent a room for them in the city," he said proudly.

It is the fourth consecutive season that the smallholder farmers of this village have been making use of the bacteria they buy from the university through the extension workers, who also showed them how to improve their farming practices.

There are 100 000 soy farmers around Benin, and the use of the new technique is spreading fast, said Fortuné Amonsou Biaou, Executive Director of the National Union of Soybean Producers of Benin. Seeing yields triple or even quadruple is very common, he said. Depending on the region, farmers used to harvest between 500 and 800 kilograms of soybean per hectare. This has now increased to between 1.2 and 2 tons. This is particularly important in this primarily agricultural country, where over half of the population is engaged in farming, which makes up 40% of the economy.

Soybean is used to make vegetable oil and animal fodder, and is also a major export crop on regional markets. "By also increasing maize yields, we increase food security for the rural population, while the higher soybean production increases their disposable income," Amonsou Biaou said.

Houngnandan founded the laboratory in 2002 to research the impact of intercropping on yields. Experiments with the use of isotopic techniques and the inoculants began a few years later, and field experiments followed in 2008. A few farmers started to use the technique as part of a pilot project in 2011, with large-scale use beginning in 2013, when the growers' association and local agricultural authorities joined in to promote it. During the 2016-2017 growing season, the laboratory produced 16 000 bags of the inoculant bacteria in the form of biofertilizers.

"It has taken us a while to scale up, but the results are very clear now," said Houngnandan while demonstrating the use of the equipment he has received from the IAEA. "I hope that in a few years every single farmer will be using it."

The Science: nitrogen uptake from the air

Scientists have known for decades that legumes can convert nitrogen from the air and deposit it in the plant and in the soil, thereby improving soil fertility. What they did not know until recently was how to measure accurately the amount of nitrogen that can be taken up by each type of crop and how to enhance legumes' ability to fix more.

When legumes are inoculated with a dose of bacteria, their ability to fix nitrogen from the air increases dramatically, as the bacteria facilitates the development of the nodules on legume roots that fix nitrogen. Researchers at the Joint FAO/IAEA Division have promoted the nitrogen-15 isotopic technique to measure how much nitrogen the legume absorbs from the air. It is based on the use of a labelled isotope of nitrogen, which has the same chemical properties as ordinary nitrogen, but contains an extra neutron, which allows it to be tracked. This nitrogen-15 methodology can also be used to estimate how efficiently cereal crops such as maize, rice and wheat absorb nitrogen fertilizer applied to maximize crop yields.

— By Miklos Gaspar

New app helps customs officers improve radiation detection for nuclear security

Every truck entering or leaving Cambodian ports passes through a radiation portal monitor – see the white panels with the red, orange and blue buttons. One third of shipments at the Phnom Penh port set off this alarm, even if they contain only harmless amounts of naturally occurring radiation. A new app developed by the IAEA will help customs officers zoom in on the shipments that may really contain smuggled radioactive material.

(M. Gaspar/IAEA)

Customs officer Mengsrom Song and his colleagues are used to the sound of radiation alarms. One third of cargo container shipments passing through the Phnom Penh Autonomous Port set off alarms on the sensitive radiation portal monitors intended to catch smuggled radiation sources and nuclear material.

However, all the alerts since the device was installed in July 2016 have been caused by material such as tiles, fertilizers and construction materials, said Song, deputy chief of the customs office at the port, located on the Mekong River just outside the Cambodian capital, Phnom Penh. The port handles one quarter of the country's foreign trade.

"Evaluating radiation alarms represents a huge challenge for us, as they require us to perform secondary inspections on dozens of containers a day," Song said. "This takes time and resources, and detracts from our other work." Secondary inspections involve the time-consuming use of hand-held radionuclide identification devices, which measure the amount of radiation and identify its type and source, as well as analysis of the data from the radiation portal monitor to check the type and origin of the commodity.

A new smartphone application launched by the IAEA will help to distinguish between alarms caused by harmless amounts of naturally occurring radiation and alarms that might be a cause for concern from a security standpoint and warrant further investigation.

The app is the outcome of an IAEA-coordinated research project that aims to improve the assessment of initial alarms. Researchers from the IAEA and 20 countries have worked together to improve the alarm assessment process by developing tools and algorithms for the detection software, with the goal of enabling it to distinguish between

A customs officer performing a secondary inspection on a truck that set off the port's radiation alarm. The handheld device confirms that the alarm was triggered by harmless amounts of naturally occurring radiation from potassium-40 isotopes, rather than from smuggled radioactive sources or nuclear material.
(M. Gaspar/IAEA)

radiation from potentially smuggled man-made sources and naturally occurring radiation.

Download the app from iTunes and Google Play.

The key to the research is being able to distinguish between the radiation characteristics of these different substances, said Charles Massey, nuclear security officer at the IAEA, who coordinates the research. The distinction cannot be based on the quantity of radiation, because the detectors need to catch even small amounts of nuclear or other radioactive material that may be present. Instead, researchers are looking into ways to identify the make-up of radiation from the different isotopes that characterize each material. The software will need to identify and record these, so that it can screen out radiation from naturally occurring materials that match the same profiles. This would filter out most of the innocent alarms, allowing customs officers to concentrate on the remaining unclear cases.

Researchers are working on new algorithms for use in the software programs to be installed in the detection systems. In the meantime, the new app, called TRACE (Tool for Radiation Alarm and Commodity Evaluation) provides a detailed compendium of naturally occurring radioactive substances and their typical radiation characteristics. "This is a big step in the right direction, as using the app will reduce the time spent deciding whether a container setting off the alarm requires further investigation," said Sokkim Kreng, customs officer at Cambodia's largest seaport in Sihanoukville.

IAEA guidance recommends that countries use radiation detection equipment as part of their national nuclear security programmes to check exports and imports of commercial goods, as a way to intercept smuggled nuclear and radioactive material.

— *By Miklos Gaspar*

Nuclear safeguards conclusions presented in 2016 Safeguards Implementation Report

IAEA Safeguards Environmental Sample Laboratory in Seibersdorf, Austria.
(Photo: D. Calma/IAEA)

In 2016, the IAEA was able to conclude that for 69 countries, all nuclear material remained in peaceful activities. For another 104 countries, the Agency concluded that declared nuclear material remained in peaceful activities. This information was presented to the IAEA Board of Governors in the annual Safeguards Implementation Report (SIR) on 14 June 2017.

"Our drawing of safeguards conclusions is very important to Member States," said IAEA Director General Yukiya Amano. "Safeguards conclusions are based on a rigorous technical evaluation of information, including that gathered by our inspectors in the field and expert analysis at our headquarters over the past year."

The type of conclusion that the IAEA draws with respect to each State varies according to the type of safeguards agreement the State has in place with the IAEA. More information on the different types of nuclear safeguards agreements can be found here: https://www.iaea.org/topics/safeguards-legal-framework.

Only in countries with both a comprehensive safeguards agreement and an additional protocol in force does the IAEA have sufficient information and access to provide credible assurances to the international community of both the non-diversion of declared nuclear material from peaceful nuclear activities and the absence of undeclared nuclear material and activities.

For three States that are not party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and have item-specific safeguards agreements

in force, the IAEA concluded that, for these States, nuclear material, facilities or other items to which safeguards had been applied remained in peaceful activities.

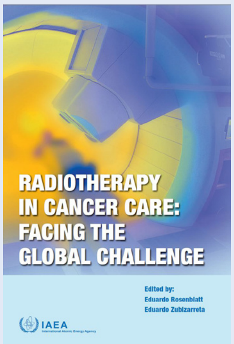
For the five NPT nuclear-weapon States that have voluntary offer agreements in force, the IAEA concluded that nuclear material in selected facilities remained in peaceful activities or had been withdrawn from safeguards as provided for in the agreements.

In 2016, twelve States Parties to the NPT had yet to bring into force comprehensive safeguards agreements with the IAEA as required by Article III of that Treaty. For these States Parties, the Agency could not draw any safeguards conclusions.

The infographic above provides further information on the IAEA's verification and monitoring activities conducted in 2016.

What are Safeguards?

Safeguards are a set of technical measures by which the IAEA seeks to verify that a State is living up to its international undertakings not to use peaceful nuclear programmes for weapons purposes. Under the NPT, non-nuclear-weapon States are required to conclude a comprehensive safeguards agreement with the IAEA that obliges States to accept safeguards. Countries with a comprehensive safeguards agreement in force have to declare all nuclear material and facilities to the IAEA. The IAEA then independently verifies these declarations. This safeguards agreement can be supplemented with an additional protocol which significantly increases the IAEA's ability to verify the peaceful use of all nuclear material in a State.



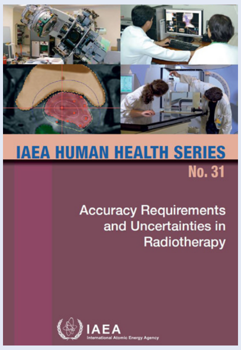
Radiotherapy in Cancer Care: Facing the Global Challenge

presents a comprehensive overview of the major topics and issues to be taken into consideration when planning a strategy to address cancer diagnosis and treatment, in particular in low and middle income countries. Cancer treatment is complex and calls for a diverse set of services. Radiotherapy is recognized as an essential tool in the treatment and palliation of cancer.

Currently, access to radiation treatment is limited in many countries and non-existent in some. This lack of radiotherapy resources exacerbates the burden of disease and underscores the continuing health care disparity among States. Closing this gap represents an essential measure in addressing this global health equity problem.

Containing contributions from leaders in the field, it provides an introduction to the achievements and issues involved in the use of radiation therapy as a cancer treatment modality around the world. Dedicated chapters focus on proton therapy, carbon ion radiotherapy, intraoperative radiotherapy, radiotherapy for children, HIV/AIDS related malignancies, and costing and quality management issues.

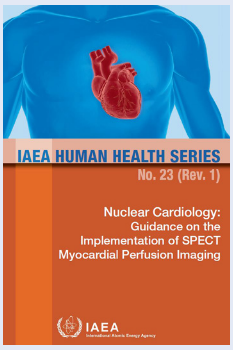
Non-serial Publications; ISBN: 978-92-0-115013-4; English edition; 62.00 euros; 2017
http://www-pub.iaea.org/books/IAEABooks/10627/Cancer



Accuracy Requirements and Uncertainties in Radiotherapy

addresses accuracy and uncertainty issues that are relevant to the vast majority of radiotherapy departments, including those offering both external beam radiotherapy and brachytherapy services. It covers clinical, radiobiological, dosimetric, technical and physical aspects.

IAEA Human Health Series No. 31; ISBN: 978-92-0-100815-2; English edition; 76.00 euros; 2016
http://www-pub.iaea.org/books/IAEABooks/10668/Accuracy



Nuclear Cardiology: Guidance on the Implementation of SPECT Myocardial Perfusion Imaging

provides a detailed analysis of all the steps involved in the delivery of nuclear cardiology services, from referrals to reporting, and is intended to serve as guidance for the implementation, homogenization and enhancement of myocardial perfusion imaging practice in those Member States where the technique is under development.

IAEA Human Health Series No. 23 (Rev. 1); ISBN: 978-92-0-107616-8; English edition; 46.00 euros; 2016
http://www-pub.iaea.org/books/IAEABooks/11076/Cardiology

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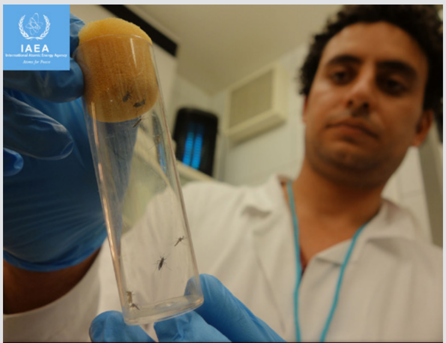

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