CHALLENGES OF MAKING RADIOTHERAPY ACCESSIBLE IN DEVELOPING COUNTRIES

MASSOUD SAMIEI[1], INDEPENDENT INTERNATIONAL EXPERT
COLLABORATING WITH THE IAEA, WHO, IARC, UICC, OXFORD UNIVERSITY AND INCTR

Following the adoption of the UN resolution on Prevention and Control of Noncommunicable Diseases (NCDs) in 2011, and the targets set by the World Health Assembly in 2012, health authorities in low- and middle-income countries (LMIC) have embarked on strengthening and integrating NCD policies and programmes into national health-planning processes. In this context, providing equitable and affordable access to cancer care for all who need it, and making the essential medicine, health technologies and specialists available, is a high priority for cancer control, where radiotherapy remains a vital and cost-effective intervention. However, planners and investors in LMIC face major obstacles in the delivery of radiotherapy services, including a shortage of 5,000 megavoltage units; accessibility and affordability of treatment; lack of a workforce of clinicians, nurses and support staff needed to run radiotherapy clinics, and their education and training; the choice of technologies and suppliers; and maintenance of equipment, among others. These challenges are discussed in this paper along with brief references to the IAEA's efforts to address the problem and its PACT initiative.

In 2010, there were 7.5 million new cases of cancer in LMIC less than 30% of whom had access to any reasonable treatment services. With increased population age, due to improvements in primary health care and survival from communicable diseases[2], as well as adoption of unhealthy life styles, populations in LMIC face an expected rise in annual cancer incidence of nearly 70% by 2030 over the 2010 rates[3].

Cancer is however not a death sentence; there are proven ways to prevent and cure cancer. The good news is that medicine, health technologies, skills and experience already exist to treat and cure cancer. All people in LMIC deserve full access to cancer prevention and care. Over 40% of cancers can be prevented, and a third can be successfully cured.

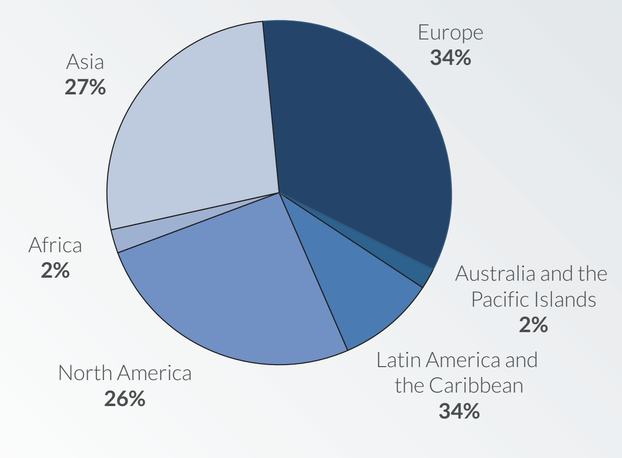
Thus, the question of providing affordable means of treating this growing number of patients, particularly in terms of medicine and health technology such as diagnostic radiology and radiotherapy, has become increasingly prominent in the minds of policy-makers in LMIC, in addition to concerns about the most feasible strategies for cancer prevention and control. If they could do for all what we do for a few, millions of lives could be saved. This has also been a priority for many UN agencies and active international organizations such as the UICC[4] and INCTR[5], but has been given a new emphasis following the comprehensive resolution approved by all UN Member States in September 2011 on the prevention and control of NCDs, among which cancer is a leading cause of death[6]. The matter has been given even higher urgency following the 2012 World Health Assembly's decision to set a global target of 25% reduction of premature mortality from NCDs by 2025 as a key target, among another 10 targets, for the implementation of the UN resolution[7].

Within the UN system, the International Atomic Energy Agency (IAEA) has a unique role to work with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies for sustainable development in food and agriculture, environmental protection, energy, industry and health. In health, radiation

Table 1: Estimated trends in cancer incidence[8]

	2010	2020	2030
More developed countries	5,719,728	6,583,577	7,425,611
Less developed countries	7,521,150	9,917,509	12,876,263

Figure 1: Distribution of the megavoltage units per region of the World



Source: IAEA-DIRAC

medicine know-how and technologies[9,10] are indispensable for cancer diagnosis, cure and care, where radiation and radioactivity play fundamental roles.

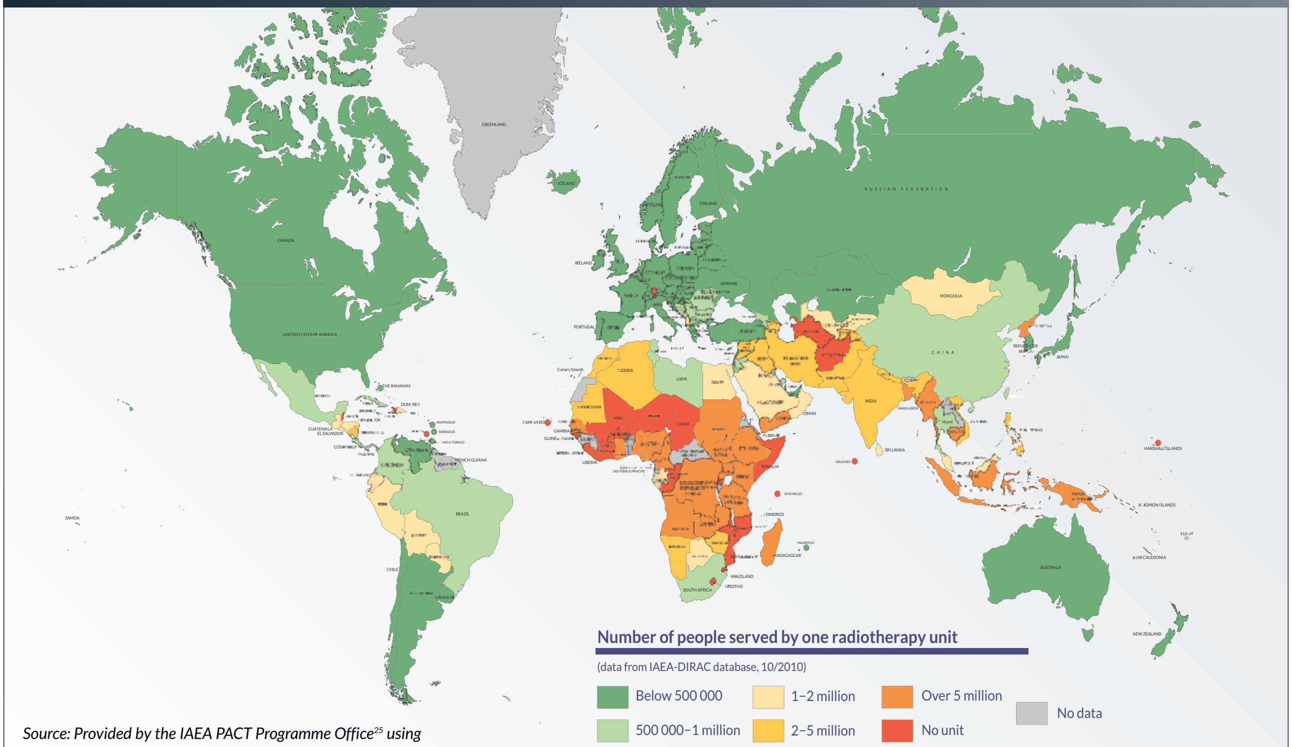
Worldwide, radiotherapy is a major part of investments in the fight against cancer. Depending on the type of cancer, on average some 50–60% of all cancer patients require radiotherapy during the course of their disease, either on its own or in combination with surgery, chemotherapy, hormonal therapy, or immunotherapy[11,12]. Over the past 40 years, the IAEA has developed strong technical expertise and acquired unrivalled experience in working with LMIC to build capacity in diagnostic radiology, nuclear medicine and radiotherapy services at national level. It has mechanisms in place to provide assistance in all relevant aspects, such as needs assessment, planning, training, econometric analysis, implementation, and development of radiation protection, safety and security infrastructure[10].

Although, due the limited funding available to the IAEA, this assistance remains far from adequate to respond fully to the growing demand caused by the looming cancer epidemic, it has gradually enabled many countries to gain experience in providing higher quality cancer treatment and care to at least a portion of their patients, while also creating more awareness about the enormity of the problem[13]. Some of the key challenges which will be faced by LMIC governments and investors attempting to address the problem, especially in response to the UN resolution on NCDs, are discussed here.

Experience with radiotherapy in developing countries

The reality in LMIC is harsh. Despite being home to 85% of the world's population, there are only around 4,400 megavoltage machines in LMIC, less than 35% of the world's radiotherapy facilities[11,14], leaving most cancer patients in LMICs without any access to potentially life-saving radiotherapy treatment. The current incidence of cancer in LMIC (about 8 million new

Figure 2: Global access to radiotherapy



Source: Provided by the IAEA PACT Programme Office[25] using IAEA's DIRAC database[26] and other available information cases per year[15]) indicates a need for about 9,600 units (see below calculation methodology); a shortage of over 5,000 megavoltage machines. This inequity goes even further when comparing the availability of radiotherapy services across regions. For example, as can be seen in Figure 1, Europe has 17 times as many radiotherapy units as are available in Africa per million inhabitants, while Latin America and the Caribbean region has just one-third of the number of machines available per capita in North America[16,12].

The lack of availability in radiotherapy treatment does not stem from a lesser need in LMIC. In fact, the needs are higher than high-income countries, because due to an absence of effective prevention and early detection and screening services, as well as lack of adequate diagnostic and treatment facilities, a higher proportion of cancers in LMIC are detected at an advanced stage, leaving palliative radiotherapy (or use of opioids) as one of the only options for treatment, even for cancers that, when detected in earlier stages, have curative treatment options[12]. In this regard, the role of radiotherapy in the palliative care of cancer patients is particularly relevant for LMIC (and probably will remain as important in the next decade or two according to many experts)[17,18]. The symptoms most commonly relieved with palliative radiotherapy are pain, bleeding and organ obstruction caused by tumours[17]. The cost of a single fraction of palliative treatment may be less than US$5 in developing countries where staff costs are also low[18]. This compares very favourably to some of the chemotherapy regimens, which can only be palliative for metastatic common solid tumours[17,20]. Palliative radiotherapy is a cost effective modality, but the extent provided depends on resources available[19]. Currently, over 80% of megavoltage cobalt machines available in many LMIC are providing nothing but palliative treatment[21,22] (which, incidentally, requires less planning and radiation fractionations and thus increases the throughput of the machine[17]). Although palliative radiotherapy as a medical practice has well-established procedures and guidelines[17,19], it is reported that due to the overwhelming number of patients seeking treatment, and the severe shortage of radiotherapy equipment and workforce in LMIC, the staff are sometimes forced to compromise on simulation, dosimetry and frequent machine calibration in order to treat more patients. This is not of course a desirable situation, since in the first place it is not in line with safety standards and IAEA and WHO guidelines and recommendations regarding the use of ionizing radiation in medicine[23,24], and secondly, it does not allow radiotherapy to develop to its full potential in LMIC and acquire recognition as an effective curative intervention, as it is elsewhere. It might also discourage further investments in these countries by donors due to fears of accidents or malpractice.

To have a closer look at the reality in LMIC, it would be useful to refer to a detailed map on "Global access to radiotherapy" (Figure 2) provided by the IAEA PACT Programme Office[25] using IAEA´s DIRAC database[26] and other available information.

The following considerations may help clarify the significance of the numbers on the map:

- According to a study in Australia, supported by other work in Sweden and Canada, for every 1,000 new cancer patients, 523 would need radiotherapy as part of their treatment (52%), out of which 120 patients (23%) would require re-treatment[12,27]. The IAEA experience, however, suggests that in developing countries this figure is higher; at least 60%[19]. This rate will remain higher in the next decades until cancer prevention and early detection programmes, as well as other cancer services and public education programmes are operational and effective in LMIC.
- Based on acceptable international standards for a sustainable delivery of radiotherapy[28], and several expert reviews by the IAEA[11], it is recommended that each radiotherapy machine should treat on average up to 500 patients per year (can be higher when fully utilized in shifts). Since some patients will require re-treatment, the number of treatment courses per year per machine will be higher than the number of incident cases requiring radiotherapy.

Table 2: Crude cancer incidence for the LMIC regions

Region	Crude cancer incidence/ million population	60% needing RT treatment	Add 23% for Re-treatment	Number of RT units/ million population
Africa	725	435	535	1
Asia	1,487	892	1,097	2
East Asia	2,370	1,422	1,749	>3
West Asia	999	599	737	>1
Latin America and the Caribbean	1,573	944	1,161	>2
Average All LMIC	**1,280**	**768**	**944**	**2**
Europe	**4,381**	**2,629**	**3,233**	**6**

- ➤ The crude cancer incidence rate is the vital input for determining the number of treatments (and thus the number of radiotherapy machines) needed for a specific country. (Age-standardised rates, on the other hand, are used for cancer risk assessment and epidemiological studies)[29].

The crude cancer incidence in LMIC is in the range of 500–2,500 per 1,000,000 people. However, depending on the region and their particular population pyramid, the average crude rate varies quite substantially[3,30]. Table 2 provides the crude cancer incidence for the LMIC regions and summarizes the need for radiotherapy (RT) machines in these regions based on the above assumptions.

It can thus be concluded that with current cancer incidence in the LMIC, and depending on the region, from 1–3 radiotherapy machines per one million population would be needed in normal circumstances (in high-income countries the ratio is 5–8 machines for one million population[11] due to a much higher crude cancer incidence as can be seen in Table 2). More accurate figures can be estimated at country level for planning and investment purposes by factoring in re-treatment courses and cancer site-specific RT requirements. Incidentally, the IAEA recommended basic radiotherapy clinic[11,19] starts treatment with one megavoltage machine (but has provisions for an additional unit) and one high-dose rate brachytherapy. Existing evidence shows clearly that large centres with more units (like centralized regional facilities in densely populated urban areas) are more cost-effective and efficient given adequate minimum staffing and resources[29].

As can be seen on the PACT radiotherapy map, most LMIC have one machine for up to 5 million population or above (less than 0.2 machines per million!). Over 30 African and Asian countries have no services at all and in several others there is a single cobalt unit for over 30–40 million inhabitants. A few LMIC in Latin America and Asia have one machine per one million and below. Under these circumstances, recalling the acute need for palliative care, the radiotherapy clinics in most LMIC are overcrowded and unable to cope with the demand. As a result, in many countries the number of new patients treated per machine exceeds the recommended number of 500, often reaching 1,000 or more per machine per year with increased operating shifts.

To realize the severity of the situation portrayed by the map, and have comparable numbers, we must calculate the percentage of cancer patients needing radiotherapy a country can cover with its existing machines by dividing the number of machine they have to the number they need ideally based on country's annual crude cancer incidence and the above assumptions. One can look more closely at Africa, where the majority of countries lack adequate services.

One among many examples of low availability of radiotherapy is Uganda, where there is only one radiotherapy service available to treat the country's 27,100 yearly cancer cases. In order to treat the portion of these patients in need of radiotherapy, this single machine must annually treat about 16,000 people, a number that is 32 times the annual number of patients a radiotherapy unit can handle. Today, with the heroic efforts of staff and clinicians at the radiotherapy hospital in Kampala, about a 1,000 of these patients are treated, i.e. 5% coverage and leaving 95% without the opportunity to benefit from radiotherapy. Uganda needs at least about 20 operational radiotherapy units in order to respond adequately to its population demands. The lack of radiotherapy availability greatly reduces the number of patients who can actually receive treatment, and makes provision of treatment an unattainable option for many living in Uganda. The over-reliance on just one unit obviously causes prolonged waiting times for receiving treatment and affects the timing between the administration of radiation doses, which can seriously compromise clinical outcomes and treatment effectiveness[16]. The situation is not much better elsewhere in Africa. Only Egypt, with 85% coverage of cancer patients needing radiotherapy, Morocco with 89% coverage, and South Africa with about 100% coverage have an acceptable situation, although equitable access to these facilities and patients' possibility of affording the treatment remains a question discussed further below. Libya also has an adequate number of machines, as can be seen on the radiotherapy map, however not all the machines available are utilized due to lack of cancer professionals[31].

Inequity of access to radiotherapy goes beyond just availability. Accessibility of radiotherapy is another challenge. In order for radiotherapy to be accessible, it must be provided in a way that takes into account the geographic distribution of the population and the direct and indirect costs of receiving treatment (considering distances to be travelled by patients and their caring close family members to treatment centres, as well as affordability and distribution of treatment services, among others). Accessibility can even be an issue in upper-middle income countries, which maintain large numbers of cancer centres, but have inconsistencies in treatment accessibility across the country. In Brazil, which has 250 radiotherapy units treating roughly 650 patients per machine, it is estimated that 86,000 patients, or over 25% of all Brazilian cancer patients, have no access to treatment each year, not because of lack of availability, but because of distribution discrepancies[32]. Over half of all radiotherapy units are located in southern region, and the best-developed centres are in the private sector leaving some entire areas with just a few machines to treat thousands of new patients. These numbers demonstrate that, even if extensive numbers of radiotherapy units are present in a country, it does not guarantee that these units provide equitable access to all of those seeking radiotherapy. Accessibility is even more of a problem where availability is limited. For instance, Zambia, a low-income country, established its first cancer centre in 2006 in Lusaka with IAEA support. Nevertheless, this centre, the only one in the country, is located over 1,000 kilometres from population concentrations near Zambia's borders, making it much harder for many patients who cannot afford the travel to, and stay in, the capital to seek treatment. These examples demonstrate that radiotherapy must not only be available, it must also be equitably accessible to all populations. Thus, access and not only availability is a vital determinant for outcomes.

Beyond the issues of availability and distribution of radiotherapy facilities, another factor influencing outcomes for patients is affordability of treatment. The costs associated with treatment contribute to the global inaccessibility of cancer services in most countries. For example, when looking at the price of radiotherapy treatment compared to incomes in LMIC, the cost is staggering, and most patients, having no health insurance, would find it impossible to pay for treatment on their own. The inability to pay for treatment could create a different form of inaccessibility that prevents even those in close proximity to a cancer centre from receiving treatment. Even in LMIC that maintain government-owned radiotherapy facilities with the potential to provide therapy for free or at a negligible cost to the patient, these facilities are commonly charged through social security fees, which could make treatment unattainable for the low-income portions of society[16]. For those who can afford social security, the economic cost of treatment is then shared with the government. In Ethiopia, only a limited portion of the population receives state-provided health insurance, but, even for those lucky enough to have some assistance in paying health costs, when it comes to cancer, the insurance only covers a maximum of 25% of fees spent in public hospitals for diagnostic, surgery and radiotherapy, and provides no support for chemotherapy or palliative care costs. In Indonesia, a different situation can be found, with the poorest segments of society receiving treatment funded by public health insurance, but the "middle class", being ineligible for public funding, generally do not have the means to pay for relatively expensive treatments offered by private hospitals. Compulsory health insurance is the norm in other countries, such as Moldova, where the state covers 55% of costs, leaving the patient to pay the remaining balance.

With so many diverse methods of costing radiotherapy services for patients in LMIC, it is difficult to say that there is one general cost for radiotherapy, but it can be seen that making treatment affordable to patients requires some form of cost sharing between the patient and the government. When governments bear a portion of cancer treatment cost, that burden is directly based on establishing radiotherapy clinics by procuring and maintaining all the essential equipment, operating the facilities and paying staff. With the average initial investment for a standard (or basic) radiotherapy clinic with two megavoltage units around US$5–6 million (including building, equipment and human resource development – the latter is an essential investment for developing countries as they need to train the workforce for each new cancer clinic), many countries are deterred by such capital costs associated with initiating a national radiotherapy service[12]. These investments can however be amortised over the life of the building and equipment, which is generally taken as 20 years. Depending on the discount rate used and the type of equipment, this may be in the range of US$250,000 to US$400,000 annually for LMIC. In addition to these costs, there are operational and auxiliary costs for staff salaries, overheads and materials, including source replacement, and quality assurance that are required over time. These costs can run to anything from US$150,000 to US$250,000 annually.

Yet, despite these expenses, the administration of radiotherapy, when evaluated per fraction throughout the lifetime of a machine (normally 20 years), is actually a relatively cheap procedure[19]. Even after factoring in all levels of cost related to the procurement, maintenance and operation of a machine, estimates from 2004 place the cost per fraction for a cobalt machine at a median of US$4.87 and for linacs at a median of US$11.02 (these figures do not include the costs for physicians)[20]. Chemotherapy costs estimated in the same manner can reach over US$600 per treatment[20]. In view of the above and many similar studies, radiotherapy is considered to be a cost-effective intervention. With radiotherapy's low fraction cost, it has been estimated that, when curative treatment has been received by an individual, upon their return to work, the costs accrued by the government for providing this radiotherapy treatment will be regained in the form of that individual's economic contribution over the course of a few years. The exact number of years required depends on a country's gross national income (GNI) per capita as defined by the World Bank[33]. In a recent study, it was estimated that the mean break-even point on a radiotherapy investment for low-income, low-middle and upper-middle income countries is 12.1, 4.5 and 1.9 years, respectively[34]. When analysing results from treatment in high-income countries, it is found that 60% of adult cancer patients are still alive five years after treatment, making the prospect of reaching these break-even points quite feasible[35,36]. In this respect, it could be argued that when investment in a radiotherapy service leads to improved quality of life and survival, radiotherapy could be considered part of a cost-effective solution to the growing cancer problem. However, it must also be noted that curative treatment is not very common in LMIC. Unfortunately, due to the absence of public awareness and adequate cancer services, the majority of cases currently present at stage III or IV, making palliative radiotherapy and end-of-life care the only possible form of treatment.

Outside of the realm of costs, other challenges that can arise in the establishment of a radiotherapy service are in the selection and procurement of radiotherapy equipment. The first issue these days is the choice between cobalt machines and the linear accelerators or linacs. Cobalt-60 units have traditionally been considered the more robust work horses to place in new cancer clinics in developing countries. Their cost is lower, and they are easier to operate for treatment delivery, planning, and maintenance[21]. However, cobalt machines have become much more sophisticated and their prices have increased. Also the cost of cobalt-60 sources is much higher and there are heightened security concerns after the 9/11 incident making the transport and return of spent sources more complicated. Some linac manufacturers have also provided incentives like participating in the investment at country level through joint ventures (some good examples are in Peru, Turkey and Vietnam). As a result, there are already many developing countries in Asia and Latin America (and a few in Africa) who are operating linacs, though with some maintenance issues. On the other hand, a few manufacturers have recently placed on the market small, single-energy linacs (4-6MeV) at lower overall costs. Others are following suit. Thus, for the LMIC governments or investors, the choices could be soon roughly comparable when combining initial capital and future recurring costs between cobalt and linac machines. It is clear that the current and emerging need for teletherapy units in developing countries cannot be met by cobalt machines alone[37]. The selection of equipment will depend on the country's radiotherapy experience and its financial and technical capacity and the available workforce. For cobalt machines, which have a useful life of 20 years, in addition to their increased initial cost, the main issue today is the need to replace the cobalt-60 source every 5–6 years (about US$150,000), requiring often disposal of the old sources at very high costs (US$250,000 to US$350,000, save prior arrangements during procurement). For the cobalt-60 source, special authorization and licensing is required from other countries in transit, unless the supplier is able to use international routes and direct transport means[20]. For linacs, which can be operated for 10–12 years before replacement, the capital cost is still high and their commissioning, operation, training, QA programmes and maintenance requirements are more complex and costly[18,21]. For most LMIC, having operated and used cobalts for a number of years, a mix-choice is probably the right approach when resources are available.

The second issue is the choice of the manufacturer. For most LMIC, the radiotherapy manufacturer from which the government is purchasing a unit is generally located far from the purchasing country, most commonly in Europe or North America (though a few more producers have emerged on the market in recent years from Argentina, China, Czech Republic and India). Besides the additional transportation costs associated with this, there are also issues that arise in terms of unit maintenance, particularly the length and extent of a unit's warranty. If a unit's warranty or after-sale service is insufficient, countries that are already operating with limited resources could be confronted with the issues of finding a cobalt-60 source replacement or transporting the spent source, or needing to bring in maintenance workers and parts from Europe or North America to repair a broken cobalt or linac unit. All at high costs. Oftentimes, if the warranty has expired, or does not adequately cover the costs, a cancer centre may be forced to leave a machine non-operational, due to insufficient funds to support maintenance and upkeep or source replacement. In order to overcome problems of maintenance and support, it is important to ensure that all acquired equipment comes with a maintenance contract and that the contract is set up with a company with well established service centres close to where the radiotherapy unit will be housed. It would also be beneficial if, in areas that do not have immediate access to a radiotherapy producer, adequate local maintenance staff is trained by the supplier of the radiotherapy units and employed by the cancer centre, helping to drive down the costs associated with long-distance travel between a user and a producer.

Albania's radiotherapy programme is an example of the difficulties that can arise from the selection and procurement of equipment. Here the issue is insufficient maintenance support despite the country's serious efforts to provide cancer care services to its citizens. Having purchased one of their radiotherapy units in 2006, the cancer hospital could not at the time afford the annual maintenance proposal of the producer, which was US$110,000 annually or US$2.2 million over the course of the cobalt machine's expected 20 year lifespan.

Moreover, one of the country's three machines now requires a source replacement, which, priced at US$150,000, may take some time to acquire, leaving Albania's nearly 8,000 cancer patients to receive treatment on only two machines[38]. Yet, there remain more issues that can arise in relation to the technical support needed to run a radiotherapy unit, and that is to do with the available workforce of clinicians, nurses and support staff and their education and training. The number of staff actually involved in the operation of a radiotherapy service can vary between centres, often depending on the number of available qualified professionals. For a basic radiotherapy centre treating up to 1,000 patients a year with two megavoltage teletherapy machines, a high-dose rate brachytherapy unit and other standard equipment such as an imaging device (a conventional or computed tomography simulator), immobilisation devices, shielding devices, a treatment planning computer system and physical dosimetry tools; the IAEA recommends a staffing of around 20 (4–5 radiation oncologists, 3–4 medical physicists, 7 radiation therapy technologists, 3 radiotherapy nurses, and a maintenance engineer)[11,19]. In more detail, this team consists of a radiation oncologist-in-chief, one staff radiation oncologist per 200–250 patients, one radiation physicist for every 400 patients, one dosimetrist or physics assistant per 300 patients, one mould room technician per 600 patients, four RTTs (radiation therapy technologists) per megavoltage unit treating up to 50 patients per day, 2 RTT-simulation for every 500 patients simulated annually, and RTT-brachytherapy as needed, as well as a nurse for every 300 patients, a social worker, a dietician, a physiotherapist and a maintenance engineer or electronics technician[19]. The staff requirements will increase if special or advanced techniques such as three dimensional treatment planning or conformal radiotherapy are employed. To ensure sustainability, it is also essential that centres gradually develop their capacity for local training of some of their own staff like technologists and provide continuous education programmes.

Unfortunately, meeting the staff requirements for a radiotherapy clinic is difficult as the world faces a shortfall of 4.3 million trained health workers and 57 countries are currently experiencing a health care workforce crisis, leaving health systems everywhere with insufficient staff available to meet the needs of their patients[39]. As stated earlier, many cancer clinics across the world are short of specialists, particularly medical physicists and oncology nurses. This is the case for most of Africa, and a significant number of countries in Asia, Latin America, and even Eastern Europe considering the number of new patients and the required staffing. Lack of well trained staff results in inappropriate or underutilization of the scarce radiotherapy facilities in most LMIC. Although some international programmes, such as those supported by the IAEA or ESTRO, offer fellowships for education and training, as well as continuous professional development, for cancer professionals, the number they can train is far below demand.

When looking solely at cancer professionals, it is estimated that in Africa alone there will be a deficit of 3,000 cancer health professionals over the next 10 years[40]. Education and training of oncology professionals is an urgent issue requiring new and innovative approaches, especially utilization of e-learning and online learning[41].

Considering that some of the positions required to establish a radiotherapy service require a university degree, postgraduate studies and at least two years of clinical training, staffing radiotherapy centres will continue to be a challenge in LMIC[19]. In this context, there is an on-going discussion on the possibility of adjusting the number of professionals managing a megavoltage machine if a less complex linac requiring less dosimetry and less frequent calibration were to be developed. This issue merits a careful expert review. The IAEA guidelines clearly specify that the clinical use of ionizing radiation is a complex process and must involve highly trained personnel in a variety of interrelated activities as described above.

However, the IAEA minimum personnel requirements are adopted from the experience in more developed countries and the recommendations of ESTRO and EFOMP. In 2008, a panel of IAEA experts agreed that the personnel requirements may have to be adjusted for LMIC, where the increased ratio of palliative to radical cases and simpler and shorter treatment protocols reduce the duration of professional involvement with each patient[11].

The problem is exacerbated further in LMIC, where a lack of resources and the prospect of better pay drive trained professionals to work in high-income countries. The loss of trained medical professionals in specialized areas such as radiotherapy is an increasing problem, particularly in Africa and parts of Asia. This bears directly on the quality of radiotherapy delivered in LMIC. In many cases, the cancer care professionals who remain in the country have limited access for practice on radiotherapy and other radiation medicine equipment due to a lack of adequate facilities (and time, as most often they work in more than one normal shift), and may require additional training to apply new techniques or to operate newly acquired technologies. Additionally, workforce strength may require that a small group of professionals take on a larger-than-recommended role in the operation of machinery, requiring further specialized training to operate a radiotherapy unit efficiently and effectively.

Finally, as procuring a machine is fruitless without the proper understanding of its utilization and a sufficient workforce to operate it, while procuring a radiotherapy unit it is important that manufacturers be obliged to provide specialized training for local engineers on the use and maintenance of their product in order to ensure that those operating the machine would use it effectively and safely.

The role of the IAEA

Understanding the radiotherapy needs of its developing Member States, the IAEA has, for over forty years, worked in over 100 LMIC to deploy robust radiotherapy and nuclear medicine programmes, expending over US$250 million on cancer-related assistance under its Technical Cooperation Programme[42], with technical support provided by its Division of Human Health[43]. This has enabled many IAEA Member States to establish safe and effective diagnostic radiology, radiotherapy and nuclear medicine capacity to provide treatment and higher quality diagnosis and care to a portion of their cancer patients. The IAEA also assists Member States with appropriate advice and support for human resources capacity building. Where resources are available, this helps Member States to achieve and maintain higher standards of professional practice[43].

With the incidence of cancer on the rise in LMIC, there is an increased demand for IAEA assistance to introduce or expand radiotherapy capacity. The resources available to the IAEA are, however, inadequate to address this huge need. But the existing cancer infrastructure in these countries, although far from being able to respond fully to all needs, is potentially the best available launching platform to extend the IAEA's assistance by encouraging investments in other cancer control components, especially advocacy and public education, cancer registry and surveillance system, prevention, early detection and screening, and palliative care. Recognizing that strategic planning and capacity building for cancer therapy cannot occur without extensive collaboration with other international key players, in 2004 the IAEA established the Programme of Action for Cancer Therapy (PACT)[13,44] in support of the World Health Assembly's call to action against cancer. PACT stands as the IAEA's umbrella programme for combating cancer and builds upon IAEA's extensive experience in radiation medicine knowhow and technology[10,43]. PACT works closely with WHO, its regional offices and other key cancer control stakeholders through the WHO-IAEA Joint Programme on Cancer Control.

The Joint Programme was established in 2009 to enable LMI Member States to improve their cancer control and care capabilities by integrating radiation therapy and nuclear medicine investments into a comprehensive national cancer control programme[45].

With LMIC facing an upsurge of cancer incidence rates in the coming years and recognizing that the radiotherapy resources available to fight cancer in LMIC are negligible in some areas and non-existent in others, PACT amongst its several strategic plans has launched an initiative to engage the manufacturers, users and experts in an open forum called the Advisory Group on increasing access to Radiotherapy Technology in low- and middle-income countries (AGaRT)[46] to find the way forward to expand radiotherapy facilities. AGaRT, deemed "frugal innovation" by Harvard[47], was first conceptualized in 2009 to bring together radiotherapy manufacturers, regional experts and international organizations from around the world to find affordable, suitable and sustainable solutions to address the shortfall of radiotherapy machines in LMIC.

The rationale behind the AGaRT initiative is to make radiotherapy technology accessible to cancer patients all over the world, regardless of their location or financial situation, through the development of radiotherapy packages that address all of the aforementioned issues with provision of radiotherapy services[46]. By addressing issues of accessibility, affordability, suitability and sustainability, the IAEA through AGaRT works to increase the cost-effectiveness and feasibility of providing radiotherapy treatment and to assist LMIC to tackle their cancer burden in a practical way through partnerships with key organizations and the industry. AGaRT's aim is to encourage the development of a US$1 million radiotherapy package that integrates all essential radiotherapy technology with high quality and safety, as well as delivery, commissioning, training of maintenance staff and longer term support for maintenance. In addition to the reduced costs associated with such a machine, these radiotherapy packages will also utilize uncomplicated, easy to handle technologies that are simple to control and maintain, allowing countries without experience in operating radiotherapy units to effortlessly transition into radiotherapy use.

Also, to support the long-term sustainability of radiotherapy units, AGaRT encourages the provisions for "whole of life" support packages from radiotherapy suppliers that will ensure affordable functionality for the entire life cycle of a unit[46]. This will include evolution in the contracting of radiotherapy units, the repatriation and re-supply of radioactive sources, the development of a regional expertise for radiotherapy unit repairs in low-resource settings and financial planning that might make the initial procurement of equipment more expensive, but that has the potential to reduce aggregate costs over time.

Recalling the extreme shortage of resources and staff in LMIC facing ever increasing demand for treatment by a growing number of new cancer patients, it would be desirable to utilize initiatives such as AGaRT to press for megavoltage machines which do not require frequent calibration and dosimetry measurements or perhaps the on-site presence of a medical physicist (thus optimising the time of any physicist available). This could also have a significant impact on the mix of staff required for running a radiotherapy clinic effectively and safely.

There has already been a response to the AGaRT initiative with some radiotherapy manufacturers developing new systems that consist of megavoltage units (4–6 MeV linacs) and include several basic capabilities and software to provide for an integrated treatment system. These systems also include a warranty and training to educate operators on system use. It is hoped that more initiatives like these will continue to develop and be tailored to provide for the individual needs of regions and health systems.

Conclusions

The current situation in most LMIC with an average of less than 30% of all cancer patients having access to any services is totally unacceptable. There is a lot that the international community can do by supporting global partnerships and joint programmes among the various active key players. To meet the needs of the growing number of cancer patients a complete solution will need to be developed that can address all facets of radiotherapy acquisition and use, assisting the ever-growing number of patients in LMIC to access the radiotherapy treatment that they require. More affordable solutions to the cancer epidemic are urgently required as with each passing day the number of those afflicted with the disease climbs and the global impact of cancer continues to grow. Radiation therapy is an essential component of cancer treatment and must be made available to all who need it.

The encouraging news is the high level resolution adopted in September 2011 by the United Nations' General Assembly on Prevention and Control of Noncommunicable Diseases (NCDs) following the leadership and extensive efforts of WHO, supported by other UN agencies and a significant number of NGOs. This is the first time that the global community has recognized at the highest international forum, with strong support of all countries, the burden of NCDs, including cancer, and their serious social and economic impact in LMIC. The implementation of this resolution, as requested by the General Assembly, will open the way for the donor community to look at successful programmes and interventions that can offer suitable and sustainable solutions for developing countries. In this context, to ensure the development of effective and sustainable treatment capacity in LMIC, radiotherapy and palliative care services should be planned at the national level as an integrated component of a national cancer control programme with careful long-term infrastructure and workforce planning within the scope of targets defined to implement the resolution on NCDs.

The relative success of recent international efforts such as IAEA's PACT partnership, its AGaRT and VUCCnet initiatives, and the Joint Programme with WHO are encouraging. No doubt such collective efforts, if maintained and strengthened with support from the industry, can play a major role in making radiotherapy technology accessible and affordable to cancer patients all over the world, regardless of their location or financial means. •

Massoud Samiei, PhD, MSc, MBA, DIC has extensive planning and management experience in the application of nuclear technology for development, particularly nuclear power, fuel cycle, research reactors, and radiation health technologies. He started his professional career in Mexico's Nuclear Research Centre in 1980. During 1983–89 he worked for a number of international nuclear energy development projects. In 1989, he joined the IAEA's Department of Technical Cooperation (TC) with responsibilities for countries in Eastern Europe and the Middle East. He was head of the IAEA TC's Europe Region from 1993 to 2005. In this capacity he was responsible for the formulation of assistance programmes for some 30 states in Europe and the former Soviet Union, and for shaping up the IAEA's human health, environmental remediation, nuclear safety, nuclear power, research reactor and nuclear security related assistance to this region. In February 2005, Massoud Samiei was appointed as Programme Director of IAEA's Programme of Action for Cancer Therapy (PACT) and Head of the PACT Programme Office, a post he held untill 31 May 2012. He brought broad international experience and knowledge in development, resource mobilization, education and training and health-related nuclear technology assistance to PACT. Through innovative partnerships with WHO and other international organizations, educational and research institutions and the private sector, PACT has moved the IAEA's cancer-related programmes to a public health model where its radiotherapy intervention is being integrated into national cancer control plans to maximize the public health impact of treatment investments. By end 2011, PACT had mobilized over US$30 million from nongovernmental donors to assist developing countries to expand their cancer control and care capacity.

Massoud Samiei is currently an independent international expert collaborating with the IAEA, WHO, IARC, UICC, Oxford University and INCTR, among others.

References

[1] Former Programme Director for the International Atomic Energy Agency's (IAEA's) Programme of Action for Cancer Therapy (PACT). The author gratefully acknowledges advice received for an early draft of the paper from Dr E. Rosenblatt, Head, Applied Radiation Biology and Radiotherapy Section, IAEA Division of Human Health, and the assistance from Mr B. Gebka and Mr D. de Sousa Neves (IAEA, PACT Programme Office) early in 2012.

[2] Cancer in Developing Countries, Cancer – A neglected health problem in developing countries, INCTR website: http://www.inctr.org/about-inctr/cancer-indeveloping-countries/

[3] Globocan 2008, International Agency for Research on Cancer (IARC), Lyon, France

[4] The Union for International Cancer Control (UICC), http://wwww.uicc.org

[5] Magrath I, Cancer in low and middle-income countries, Network: *INCTR Magazine*, Vol.9, No.3, March-June 2010

[6] WHO, UN high-level meeting on non-communicable diseases prevention and control, 19-20 Sep 2011, http://www.who.int/nmh/events/un_ncd_summit2011/en/

[7] WHO, Media centre, 65th World Health Assembly closes with new global health measures, 25 May 2012, http://www.who.int/mediacentre/news/releases/2012/wha65_closes_20120526/en/index.html

[8] IARC, Cancer Fact Sheets, Globocan 2008, http://globocan.iarc.fr/factsheets/cancers/all.asp

[9] Radiation Medicine includes radiotherapy (or radiation oncology), diagnostic radiology, nuclear medicine, and medical physics. For more details see IAEA, Division of Human Health website: http://www-naweb.iaea.org/NAHU/index.html

[10] Burkart W, Chhem RK, Samiei M, IAEA, Atoms for health: The IAEA's contribution to the fight against cancer, *Health G20* (2010), http://www-naweb.iaea.org/na/G20-IAEA-article-atoms-for-health.pdf

[11] IAEA, Division of Human Health, Setting up a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects, 2008

[12] Barton MB, Frommer M, Shafiq J, Role of radiotherapy in cancer control in low-income and middle-income countries, *Lancet Onco*. 2006 Jul;7(7):584-95

[13] IAEA, Director General report, Programme of Action for Cancer Therapy, http://www.iaea.org/pact/pdf/GOV-2004-39_GeneralDistribution_final_June_2004.pdf

[14] WHO, Global status of noncommunicable diseases 2010, Chapter 5, p62, http://www.who.int/nmh/publications/ncd_report_chapter5.pdf

[15] Calculated using the online analysis tool for predictions from Globocan 2008, IARC

[16] IAEA, Human Health Reports No.3, Inequality in Cancer Care: A Global Perspective, 2011

[17] IAEA, Human Health Reports No.2, Radiotherapy in Palliative Cancer Care: Development and Implementation, 2012

[18] Shortt K, Allen BJ, Appropriate Technology for Palliative Radiotherapy, Workshop on Palliative Radiotherapy for Developing Countries, November 1, 2008, HCMC, Vietnam

[19] IAEA, Human Health Series No.14, Planning National Radiotherapy Services: A Practical Tool, 2010

[20] Van der Giessen PH et al, Multinational assessment of some operational costs of Teletherapy, *Radiotherapy and Oncology* 71(2004)347-55

[21] Allen BJ, Comparative cost analysis for Co-60 and linacs in developing countries, Workshop on Palliative Radiotherapy for Developing Countries, November 1, 2008, HCMC, Vietnam

[22] Anh LT, The case for provincial palliative radiotherapy centres in Vietnam, Workshop on Palliative Radiotherapy for Developing Countries, November 1, 2008, HCMC, Vietnam

[23] IAEA has developed extensive programmes to advise countries and train health professionals in radiation protection, dosimetry, QA/QC exercises and audits in radiation medicine to improve practices worldwide. However, there must be closer attention to existing radiotherapy clinics and more enforcement of international audits to ensure safety standards are strictly practiced and radiotherapy is delivered in accordance with protocols. See also: Chhem RK et al, Towards better and safer use of radiation in medicine, *Lancet* 375(9723):1328-30(2010), and IAEA websites: https://rpop.iaea.org/RPOP/RPoP/Comtent/index.htm, http://www-naweb.iaea.org/NAHU/index.html IAEA

[24] WHO, Radiotherapy Risk Profile, Technical Manual, 2008, http://www.who.int/patientsafety/activities/technical/radiotherapy_risk_profile.pdf

[25] Courtesy PACT Programme Office, http://cancer.iaea.org

[26] IAEA Human Health Division, DIRAC database, http://www-naweb.iaea.org/nahu/dirac/default.asp

[27] Delaney GP et al, The role of radiotherapy in cancer treatment, *Cancer* 104(6):1129-37(2005)

[28] This is strongly linked to the economic situation of the country and what is achievable in different resource settings and whether that is an acceptable standard, is a value judgement question especially with regards to the appropriateness of the infrastructure on-site and whether it is being used effectively. As indicated in the main text, in many *LMICs*, the number of treatment courses delivered far exceeds this value and is as high as 1,500 per year mainly for palliative radiotherapy.

[29] Bentzen SM et al, Towards evidence-based guidelines for radiotherapy infrastructure and staffing in Europe, *Radiotherapy and Oncology* 75 (2005) 355–365, http://www.thegreenjournal.com

[30] Cancer Research UK, Cancer Worldwide – the global picture, http://www.cancerresearchuk.org/cancer-info/cancerstats/world/the-global-picture/cancer-overall-world

[31] Egypt with 69,000 new cases of cancer per year and one machine per 1.4 million population, Libya with 5,045 new cases of cancer per year and one machine per 730,000 population, Morocco with 28,000 new cases of cancer per year and one machine per 1.1 million population, and South Africa with 75,000 new cases of cancer per year and one machine per 625,000 population)

[32] Brazil Presentation at IAEA/PACT Advisory Group on increasing access to Radiotherapy Technology (AGaRT) Meeting, Vienna, June 2010

[33] The World Bank, Newest country classification, http://data.worldbank.org/about/country-classifications and GNI per capita http://data.worldbank.org/indicator/NY.GNP.PCAP.CD

[34] Datta N, Rosenblatt E, Samiei M and Camacho R paper presented to the 4th International Cancer Control Congress, Seoul, Rep of Korea (Nov 2011)

[35] Curtiss CP, Haylock JP, State of the science on nursing approaches to managing the late and long term sequelae of cancer and cancer treatment, *American J of Nursing* 106(Suppl. 3), 2006

[36] Coleman M et al, Cancer survival in five continents: a worldwide population-based study (CONCORD), *The Lancet Oncology*, Volume 9, Issue 8, 2008

[37] Salminen E et al report on International Conference on Advances in Radiation Oncology (ICARO) held in Vienna on 27-29 April 2009, *Radiation Oncology* 2011, 6:11

[38] Personal communications with hospital staff, 2011

[39] WHO, Scaling Up, Saving Lives, a report by Global Workforce Alliance, 2008

[40] IAEA, PACT in Africa, Africa's current cancer crisis, http://www.iaea.org/Publications/Booklets/TreatingCancer/pact0610.pdf

[41] IAEA, PACT, Virtual University for Cancer Control and Regional Training Network (VUCCnet), http://cancer.iaea.org/newsstory.asp?id=69

[42] IAEA, Technical Cooperation Department, website, http://www.iaea.org/technicalcooperation/Home/index.html

[43] IAEA, Nuclear Science & Applications, Comprehensive Cancer Control, NA Fact Sheets 2011, http://www-naweb.iaea.org/na/resources-na/NA-Factsheets_PACT.pdf

[44] Samiei M, Building partnerships to stop the cancer epidemic in the developing world, UN Special, No.676, Sep 2008, http://www.unspecial.org/UNS676/t31.html

[45] WHO, Media centre, WHO, IAEA join forces to fight cancer in developing countries, http://www.who.int/mediacentre/news/releases/2009/who_iaea_cancer_programme_20090526/en/index.html

[46] IAEA, AGaRT, http://cancer.iaea.org/agart.asp and Frugal Innovation: Addressing the challenge of global access to radiotherapy, http://cancer.iaea.org/newsstory.asp?id=101

[47] Knaul FM et al, The Global Task Force on Expanded Access to Cancer Care and Control in Developing Countries, Harvard Global Equity Initiative, Closing the Cancer Divide: A Blueprint to Expand Access in Low and Middle Income Countries, Nov 2011, p167

THE UNIQUE™ SYSTEM – VARIAN ADDS RAPIDARC® AND IMAGE GUIDANCE TO LOW ENERGY TREATMENT PLATFORM FOR RADIATION THERAPY IN INTERNATIONAL CANCER CLINICS

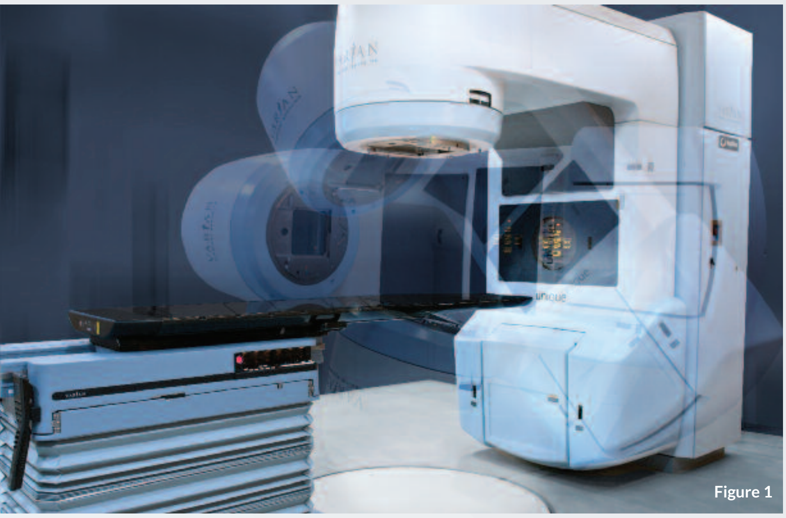


Figure 1

Figure 2

Figure 1: UNIQUE™ Linear Accelerator – core of the UNIQUE Solution

Figure 2: The UNIQUE™ PortalVision system for Image Guided Radiotherapy (IGRT)

Figure 3: RapidArc® plan of an NPC case treated on UNIQUE with excellent sparing of critical organs (data courtesy of Prince of Wales Hospital, HongKong)

Figure 4: Accurate Head & Neck Patient Setup on UNIQUE

Since Varian Medical Systems introduced its UNIQUE™ linear accelerator for international cancer clinics, the world's first low-energy radiotherapy system with image-guidance and RapidArc treatment capabilities has made advanced care more affordable and more widely available to cancer patients around the world.

The UNIQUE™ system represents a complete cost-effective radiation oncology solution featuring all components and services to build a state-of-the-art radiation therapy cancer centre.

"This package is truly a unique offering for international markets," says Kolleen Kennedy, president of Varian's Oncology Systems business. "We added high-tech image-guidance and arc therapy tools to a low energy platform together with our treatment planning and information management software so that technology for fast, state-of-the-art cancer treatments can be made available to treatment centres at a cost around US$2 million. The UNIQUE™ system is in keeping with our mission to save more lives by making proven advanced radiotherapy technology available to people who currently do not have access to it."

The UNIQUE™ Performance Edition incorporates all the tools needed to easily establish or enhance a clinically effective radiotherapy treatment operation. The UNIQUE™ platform's low energy medical linear accelerator (Figure 1) incorporates Varian's proven technologies for reliable and consistent dose control, delivery, and beam shaping, into an

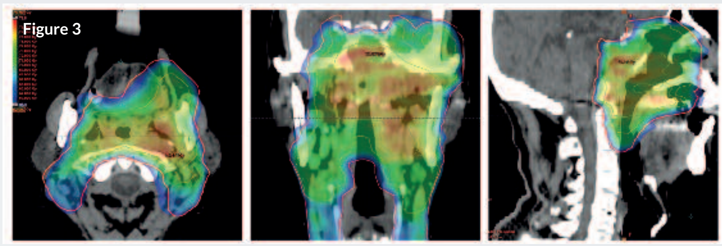


Figure 3

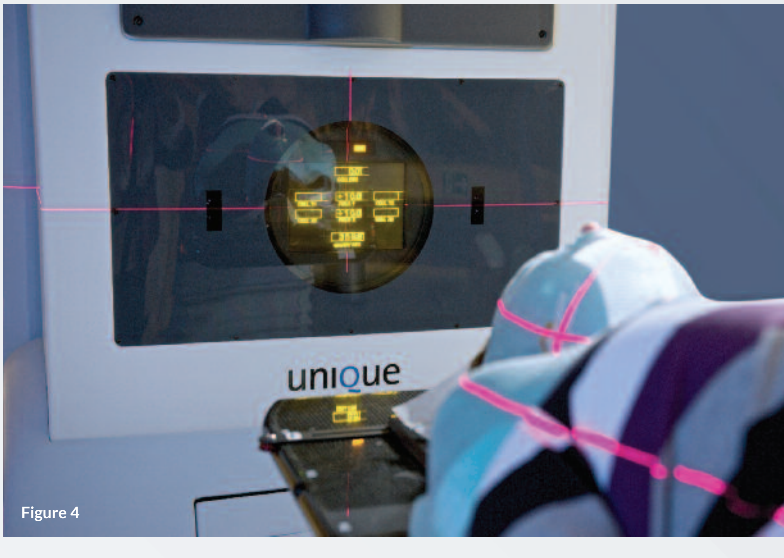


Figure 4

elegant machine with patient friendly design that is small enough to fit into almost all existing treatment bunkers. The system is ideally equipped for treating cancers of the head and neck, breast, cervix and prostate, which make up the majority of cases in most areas of the world.

"It's a comprehensive, cost-effective offering that provides cancer patients with standard treatments as well as advanced techniques, including intensity modulated radiotherapy (IMRT), image-guided radiotherapy (IGRT), and RapidArc® treatments," said Rolf Staehelin, Varian's international marketing director. "By making UNIQUE™ available with advanced capabilities developed for our high-energy platforms, we are helping more clinicians around the world to offer higher standards of care for all of their patients." (Figure 2).

UNIQUE™ also includes the latest release of Varian's market leading Eclipse treatment planning software, offering clinicians a seamless workflow for planning and delivering advanced radiotherapy treatments. It is a cost effective solution designed to make access to quality care more widely available to cancer patients around the world.

Varian also offers a UNIQUE™ Power Edition without RapidArc technology or image-guidance software, for centres that prefer to begin with a more basic yet upgradeable platform. Either system is appropriate for treatment centres looking to transition from older cobalt units to modern radiotherapy technology. The small footprint of the UNIQUE™ accelerator allows it to fit into most small, existing treatment vaults.

First in Asia

Prince of Wales Hospital in Hong Kong, China, became the first treatment centre in Asia to commence treating cancer patients using the UNIQUE system. Clinicians delivered an image-guided RapidArc® treatment for a patient battling hypopharyngeal cancer, a tumour in the lower part of the throat near the larynx.

"The UNIQUE™ system, with its capacity for fast RapidArc treatments, markedly enhances our treatment capacity," said Dr Brian Yu, Head of Radiation Oncology, Prince of Wales Hospital. "It enables our centre to provide timely precision radiotherapy to an increasing number of patients, helping to improve our throughput. This arc-based treatment shortens the treatment delivery time to less than two minutes. Our measurements show that UNIQUE™ can deliver high quality conventional IMRT and RapidArc treatments. Prince of Wales Hospital will use RapidArc as a preferred modality for treating head and neck and prostate cancer."

"With its speed and image guidance capabilities, UNIQUE™ enables cancer clinics to provide quality care to more patients at a lower cost per treatment," said Tom Duffy, Varian's vice president of sales and marketing for the Asia-Pacific region at the time of this first treatment. "We are pleased to support Prince of Wales Hospital in making this technology available to patients in this region."

The Department of Clinical Oncology at Prince of Wales Hospital in Hong Kong treats more than 3,600 cancer patients each year. It is an institution that provides integrated radiotherapy, medical oncology, haematological oncology, and palliative care services. The department is a pioneer in intensity-modulated radiotherapy for nasopharyngeal carcinoma and a leading research centre studying malignancies that are prevalent in Southeast Asia, including lung, liver, and nasopharyngeal cancers. Nasopharyngeal carcinoma (NPC) is an Epstein-Barr virus associated malignancy arising from the nasopharynx, a site less easily accessible by surgery, and is characterized by a high incidence of regional nodal metastasis. RapidArc treatment with or without chemotherapy allows a very high local control rate and potential to spare organs (Figure 3). However, primary tumors in advanced-stage NPC often extend in close proximity to important organs-at-risk such as the brainstem and optic pathway. This calls for image-guidance techniques which ensure the greatest accuracy of position and dose (Figure 4).

Since its launch, the UNIQUE™ low energy platform has been rolled out globally, with installations in many European, Asian, Latin American and African countries.

Earlier this year, Centro Oncologico Antofagasta in Chile became the first treatment centre in Latin America to commence treating cancer patients using the UNIQUE™ system, while several hospitals in sub-Saharan Africa are installing the device to offer patients more advanced radiotherapy treatments.

Clearance in China

Varian recently received clearance from China's State Food and Drug Administration (SFDA) to market the UNIQUE™ medical linear accelerator in that country.

"Epidemiological data shows that more than 2.2 million new cancer cases are diagnosed in China each year," adds Tom Duffy. "This presents the dedicated clinicians in China with daunting numbers of patients in need of treatment. Many departments operate two or three shifts to keep up with the demand for access to radiotherapy treatment. In recognition of the challenge, the Chinese Ministry of Health has announced a dramatic increase in the number of licenses available to hospitals for the purchase of additional accelerators and we are delighted that UNIQUE™ has been approved in China to help meet the resulting demand for advanced new treatment equipment." ●