THE FUTURE OF MEDICAL PHYSICS: A CASE STUDY OF ZAMBIA

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Abstract

The last few decades have seen tremendous growth in the health sector in Zambia. At the beginning of the 21st century, policies were developed and resources allocated, leading to the establishment of the first radiation treatment centre in the country; Cancer Diseases Hospital (CDH). Among the key personnel needed to run this kind of specialized hospital are medical physicists (MPs). As of January 2019, the country had less than five medical physicists on the Health Professions Council of Zambia (HPCZ) register.

In 2018, CDH had recorded about 2700 new cancer cases corresponding to a 12% increase from the past year. This value was representative of 34.7% patients with access to radiotherapy. In order to accommodate this rise in patient load, two radiotherapy centres and smaller satellite radiotherapy departments attached to existing hospitals with cancer management capabilities are envisioned. Furthermore, the Zambian Government in collaboration with ROSATOM, plan to construct the Centre for Nuclear Science and Technology (CNST); hosting Radiotherapy and Nuclear Medicine facilities also. These increases therefore, necessitate the procurement of more diagnostic and therapeutic equipment. This will subsequently require a substantial number of MPs commensurate with the International Atomic Energy Agency (IAEA) staffing recommendation.

Growth of Medical physics in Latin America, Asia and Africa was looked at and a comparison to Zambia undertaken. The IAEA tool was used to estimate the recommended staffing requirements of MPs and a comparison with the prevailing situation done from 2006 to 2019. Future projections and trends were also analysed to offer a much clearer perspective.

Results showed that the current growth in MPs is below the recommended threshold, the future trends are also indicative of a deficit which will likely not be met in the next 10 years. The following conclusions were made; the need to develop local curricula, improve enumerations and career prospects.

Keywords: Medical Physics, Medical Physicists, LMIC, IAEA, Zambia

I. Introduction

The cancer prevalence rate in low and middle income countries (LMIC) is estimated to double by 2050. This is attributed to several factors including dietary and lifestyle changes, HIV/AIDS, increased smoking and alcohol consumption. In Zambia 12052 new cases were reports in 2018, resulting in approximately over 7300 deaths (61.23 %) [1].

According to an IAEA news report in 2003 prior to setting up of the Cancer Diseases Hospital (CDH) [2], most patient with cancer had to travel to either Zimbabwe or South Africa to access radiotherapy (RT) treatment. Few, though could afford this even with the government covering most of the associated costs. The lack of proper treatment resulted in recurrences of most malignancies. This trend was greatly reduced with the opening of a radiotherapy centre in 2006 (officially opened in 2007).

The CDH has from inception to present treated over 21247 cases. This is a great milestone, considering that it recorded only 35 patients at inception [3].

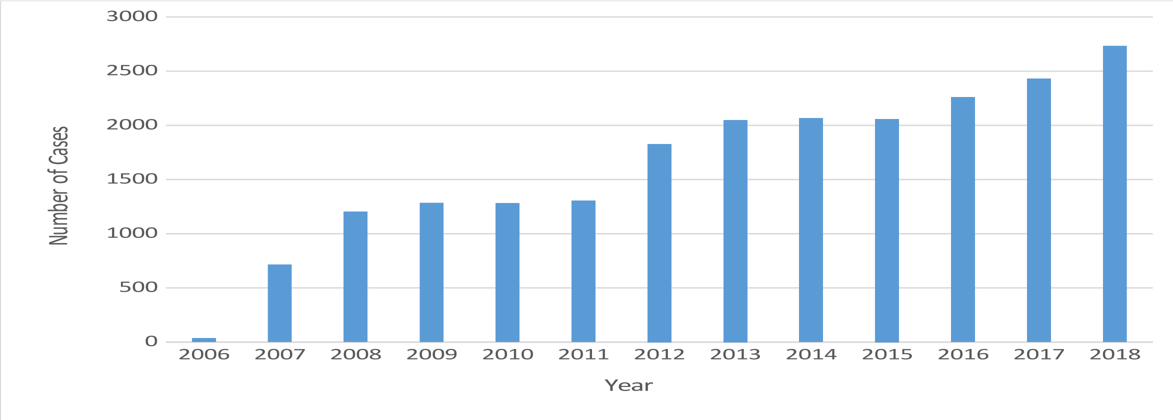

Figure 1 Cancer patients treated at CDH from 2006 to 2018. Data adapted from [3].

Radiotherapy capacity building in Zambia has been a phased approach; with the initial phase started in 2001 with funding from OPEC ($5.6M), IAEA and GRZ [2]. Total funding was estimated to be about $7M by Lishimpi [3]. Phase I mostly catered for the construction of the radiotherapy unit, with a LINAC, Co-60, auxiliary equipment and training of initial staff (radiation oncologists-RO, medical physicists and radiation therapy technicians-RTT). Phase II, commenced in 2012 and involved the expansion of the Centre to include wards, Nuclear Medicine wing, dedicated chemotherapy wing, procurement of another Co-60 teletherapy machine with an SAD of 100 m and other facilities and equipment. This phase had a funding of $8M from OFID and GRZ. In 2016 funding of about $40M from OPEC Fund for International Development (OFID), Government of the Republic of Zambia (GRZ) and others was secured to embark on the third phase. The projects under this phase are the upgrade of CDH (infrastructure, staff and equipment), setting up of 3 out of the planned 9 satellite cancer centres across the country.

Nine people have been trained in medical physics from the inception of radiotherapy in Zambia, even though the training of medical physicists has not been consistent owing to several factors. The IAEA has been facilitating clinical training, though lately academic training has been facilitated in collaboration with the International Centre for Theoretical Physics (ICTP) through fellowships in partner countries. However, other partners have come on board to offer scholarships for staff to train in the UK and other countries.

A. *CURRENT STATUS*

The country has about ten medical physicists mainly in academia, health and other allied sectors. There are five MPs in the health sector, all stationed at the CDH, in radiotherapy. Of these five, only three have undergone structured clinical training to be designated as clinically qualified medical physicists (CQMP). A report by Datta et al [4] established a deficit of about 13 MPs for the country as of 2014, though the situation has improved slightly as 3 MPs were trained and retained since then.

Table 1 IAEA Directory of radiotherapy centres (DIRAC) report for Zambia [5].

RT Centres	Clinical Accelerator.	Co-60	CT	Simulator.	TPS	HDR (Ir-192)
1	1	2	2	1	5	2

Currently there are programmes training ROs and RTT locally, but none for MPs. The current system does offer unstructured clinical training. Recently, plans to commence postgraduate studies at local universities are underway with curricula already developed. Clinical Medical Physics training will be offered in the hospital and efforts are underway to introduce this based on the Federation of African Medical Physics Organisations (FAMPO) clinical training curriculum. There is a medical physics elective in the B.Sc. Physics offered by the University of Zambia [6], while Mulungushi University has introduced a B.Sc. Physics with individual medical physics modules in radiotherapy, medical imaging and nuclear medicine physics rather than electives. A B.Sc. in Medical Physics is also being planned, with duration of five years with clinical attachments during training.

An inventory of equipment conducted in 2016 by the Ministry of Health indicated that there were about 90 public medical imaging, one nuclear medicine centre and one radiotherapy centre in Zambia; with over 250 imaging equipment and three radiotherapy equipment (Fig. 2) [6].

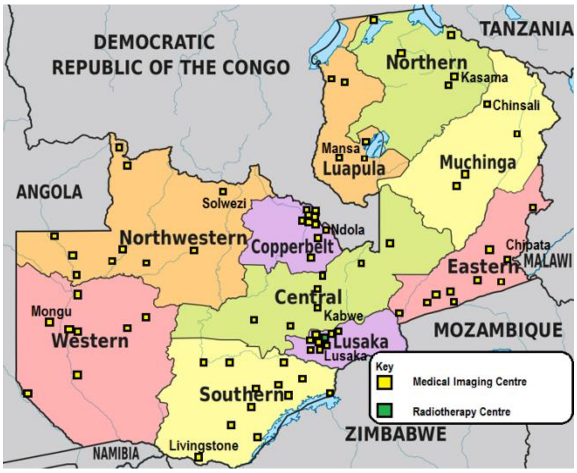

Figure 2 Distribution of Public Medical Imaging and Radiotherapy Centres in Zambia [6].

According to Vassileva et al [7] there should be a minimum of two clinically qualified Medical Physicists per Radiotherapy department, one per Diagnostic Radiology department and one per Nuclear Medicine department. Therefore, Kawesha [6] established that 94 medical physicists were required to adequately manage the equipment and patient load in the radiotherapy, diagnostic and nuclear medicine facilities around the country.

B. MEDICAL PHYSICS AROUND THE WORLD

When comparing Medical Physics scenarios around the world to Zambia, similar themes emerge. There is a high number of patients and not enough MPs in most LMIC. There are a few examples of countries with enough MPs to meet their workload demands.

In Nepal, as of 2018, there were 11 medical physicists working and five LINACs, three Cobalt Teletherapy, four Simulators, five HDR brachytherapy, one Orthovoltage, 18 MRI, 45 CT, over a thousand (1000+) x-ray, 12 Mammography, one PET and three Gamma Camera devices [8], [9]. According to their analysis, they need a minimum of twenty-five (25) Medical Physicists to manage their workload, more than double the current number.

In Cuba, as of 2014, there are 53 Medical Physicists working in Healthcare. This group is tasked with managing eight LINACs, 12 Cobalt Teletherapy, five HDR brachytherapy, three Superficial radiotherapy, 21 SPECT, two Nuclear Medicine therapy, two PET/CT, over a thousand (1000+) X-ray units, 40 CT, 31 Mammography and 535 Ultrasound devices [10]. Cuba is one of the few examples where the number of Medical Physicists is enough to meet the workload demand.

Worldwide trends show that a consented effort is underway to reduce the manpower deficit. The IAEA has actively been on the ground globally to help in this agenda. Indonesia, a LMIC, has gone through similar challenges like Zambia. In the work by Pawiro et el [11], the training of medical physicist at B.Sc. level helped reduce the critical deficit to an extent, 380+[11], [12].

C. CHALLENGES

There are five main challenges facing the field in Zambia; high patient numbers, low recruitment and retention rates of MPs, lack of academic and clinical training programmes in medical physics and lack of recognition by health authorities.

The cancer disease burden far outweighs the available staff and facilities, the required number of MPs as calculated using the RT staff calculator is 14 against 5 available MPs, a 64% deficit. This value is close to that calculated by Datta et al in 2012 [4]. It is imperative that this figure is reduced in order to achieve the vision 2030 of achieving universal health for all. Abdel-Wahab et al [13] also indicated that as of 2008, we had about 10100 cases and of these only about 6476 were in need of radiotherapy, about 64%. However, Fig. 1 shows that only 18.4% of patients actually had access to radiotherapy. On average, LMICs have percentage access of about 13.6 [4], indicative that Zambia is above average in terms of patient access to RT. In RT the IAEA has recommended a one MP to 400-450 patients per year ratio[14], translating to around 14 MPs needed as far back as 2008. The latest statistics (2018) show that there are about 7800 patients in need of RT and only about 32.4 % have access, requiring about 17-18 MPs, as calculated using the calculator. Zambia currently needs about 17-18 teletherapy equipment against the available three, representing a deficit of 82.3%.

The recruitment of MPs has been uncoordinated through the years, hence leading to challenges in meeting the required number for the Country, compounded by other factors. The retention levels have been quite low especially with the fluctuating conditions and lack of progressive structure in the sector. The low entry level requiring postgraduate qualification is not so attractive, especially with competing careers offering better conditions in academia. The high demand for MPs in the region is also grossly contributing to the low retention levels experienced in Zambia.

The current cost of training one MP is between $112,045 and $152,000 in the Europe Union [15]. For most LMIC the cost is a limiting factor, as there are competing needs such as poverty eradication and HIV/AIDS. Thus, local training is cardinal as it is affordable and answers the actual needs of the country as opposed to foreign training.

Clinical MPs register with the HPCZ as health professionals but this is done for the purpose of working in a hospital. HPCZ is a government body that conducts licencing examinations for most medical professionals. There is no body that solely looks at the welfare and professional development of medical physicists. The none availability of a professional body has adverse effect on the growth of medical physics as there is poor or lack of communication among individual medical physicists and at times the low representation leads to low levels of monetary support flowing towards medical physics related matters.

A quantitative analysis of the prevailing situation was done and predictions from existing data and global trends were done to draw trends specifically for Zambia. The data estimates have been retrieved from public domain websites of the relevant UN agencies, peer reviewed literature and on the ground sources. Proposes and recommendations have been put forward to address the challenges.

II. METHODOLOGY AND MATERIAL

Zambia with a GNI per capita PPP of $4100 is categorised as LMIC [16]. Cancer incidence rates for Zambia were obtained from the GLOBOCAN, International Agency for Research on Cancer (IARC) [1]. The incidence rates from 2006 to 2018 were used to predict incidence rates from 2020 to 2030, these were then considered to determine staff levels. The radiotherapy infrastructure retrieved from the Directory of Radiotherapy Centres (DIRAC) of the International Atomic Energy Agency (IAEA) (Supplementary Table S1) [5]. The IAEA's RO staffing calculator [14] was used to calculate the required optimal number of MPs for the period under review [14].

III. RESULTS AND DISCUSSION

The RO calculator was used to estimate the number of medical physicists required for the CDH. The average treated cases per MP over the period from 2006 to 2018 were 410, with values ranging from 35 to 716 as indicated in Fig. 3.

The IAEA recommended number for medical physicists was used to forecast requirements for the period from 2020 to 2030, shown below in Fig. 5. In order to predict values close to other predictions made in other published works and statistics, the following assumptions were taken into consideration:

1. Only 8 hours per day excluding overtime hours were considered. For a scenario were the work day is extended beyond 8 hours, there will be need for additional staffing to cover the early morning and late evening shifts.
2. The average attrition rate was calculated to be 8% for the period from 2006–2018, which was mainly due to resignations.
3. The access to radiotherapy has been increasing steadily from about 5% to 23% over the period under review, with an average of about 18%.

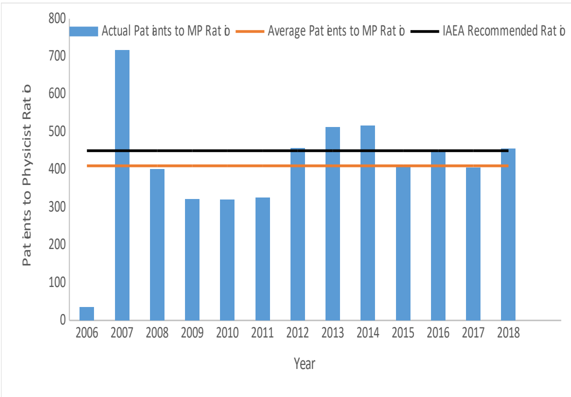

Figure 3 The patients to medical physicist ratio for the period from 2006 to 2018. Black line is the recommended value by the IAEA while the light brown line is the average over the period.

Over the period under review, the recommended levels increased from 14 to 18 medical physicists, while the actual numbers increased from one to six with an average of four. A comparison of the recommended to the actual numbers shows huge differences throughout the period.

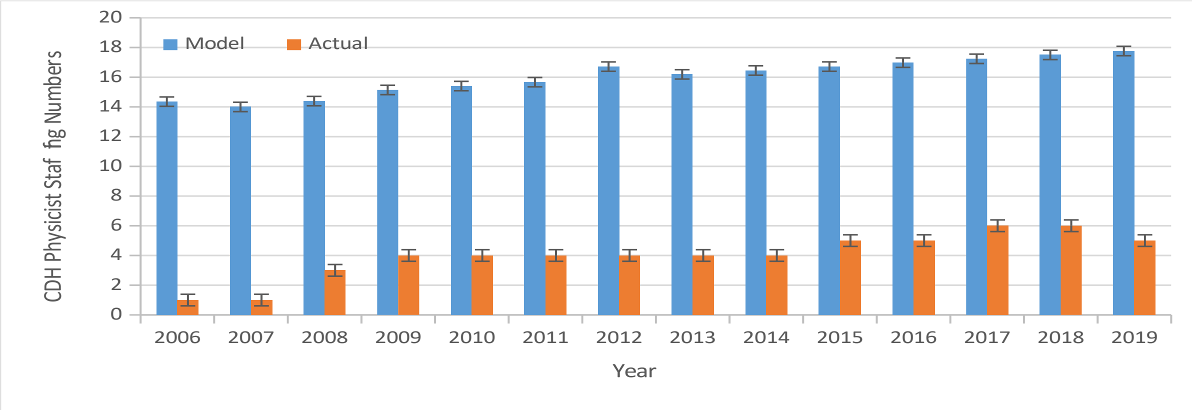

Figure 4 The actual total number of medical physicists (FTE) involved in cancer treatment at CDH for the period 2006-2019 (light brown) compared to the IAEA guidelines calculated using the RO calculator (light blue).

Our estimates indicate a deficit of about 11 medical physicists by 2030, a slight reduction. There are proactive measures already underway; the main ones being the setting up of two cancer centres in Southern and Copperbelt provinces. Assuming that the centres will each accommodate a Co-60 teletherapy machine, then they will increase the current access to radiotherapy by over 50% [3], [17]. The planned Centre for Nuclear Science and Technology is anticipated to house a radiotherapy facility with at least one LINAC on site [18], [19]. This also will translate into a recommended capacity of about 450 patients per year. There are plans by a private organisation to set up a radiotherapy centre on the Copperbelt, with the facility expected to open in mid-2020 [20]. The facility is anticipated to house two LINACs when fully operational in 2021, further improving access to radiotherapy by 900+ patients year. On overall these centres will offer 2250 patients access to life saving radiotherapy, almost doubling the current numbers.

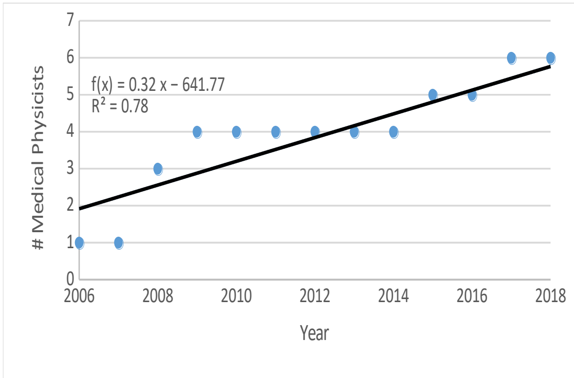

Figure 5 The trendline (black) show the steady increase of medical physicists at CDH over a 12 year period.

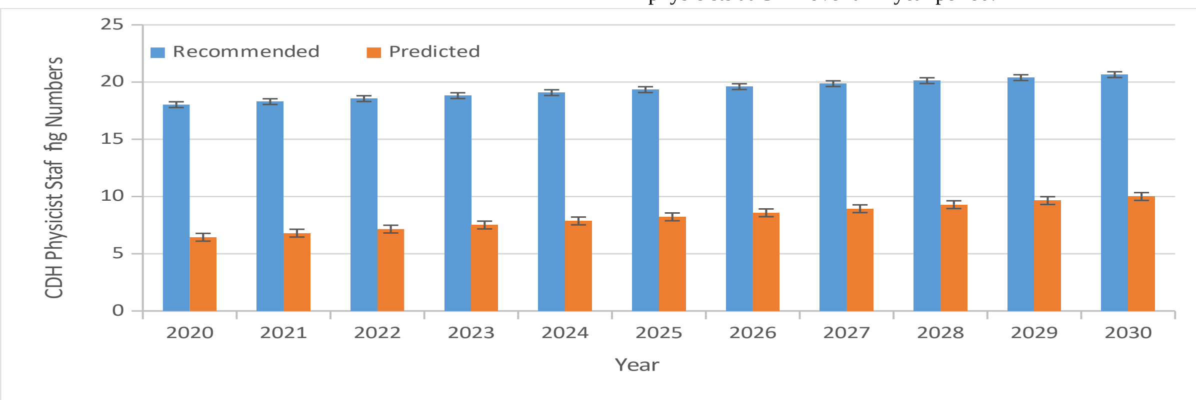

Figure 6 Correlation between the predicted and recommended numbers of FTE medical physicists at the only Zambian Centre.

The infrastructure growth will need to be matched by clinically qualified medical physicists to guarantee quality care by carrying out quality assurance of the equipment, personalised treatment planning and commissioning. There are plans to improve the current staffing levels so as to alleviate this challenge. These plans involve the commencement of a postgraduate academic programme in medical physics reinforced by clinical training, locally. There is a prevailing notion that postgraduate programmes alone may not adequately and quickly bridge the gap. There sectors advocating for an undergraduate programme in medical physics, with the core radiotherapy courses offered as a short term solution. However, the stance of most MPs is that outlined and supported by IAEA and FAMPO[21], [22]-Postgraduate (MSc) then a two to three year clinical training.

The setting up of a professional organisation will also greatly improve the information flow between medical physicists and other stakeholders. This will also provide a platform on which some of the current challenges like full recognition, retention and remuneration can be tackled.

It is interesting to note that the current level (Fig. 3) in terms of patient to physicist ratio, on average is around the recommended ratio. In comparison to the region, the patient to physicist are some of the lowest, this is without considering factors such as low access to RT and others.

The prediction of the staffing levels from 2020 to 2030 as shown in Fig.6; do show a reduction between the recommended and predicted figures. However, the required number may be higher, as there is anticipated investment by both public and private players in the sector. This period will also see improved access to high-end radiotherapy equipment on overall, therefore requiring more expertise as more complex techniques will be employed to treat cases. This will also push up the number of clinically qualified medical physicists required.

IV. Conclusion

The high attrition rate of about 100 % has been observed over the period from 2006 to 2018. This is attributed to low renumeration for MPs on average and lack of career prospects. The establishment of physics programmes in local universities has also put a strain on the available manpower. Therefore, an increased demand for physicists at the new radiotherapy centres envisioned will further increase the strain; compounding the situation. So if challenges relating to pay, career progression and structured clinical training are not addressed effectively the developmental gains will be of little significance. The creation of curricula for academic training in medical physics would offer a solution in as far as reducing the manpower deficit, but it would need to be coupled with retention measures to curb 'greener pasture' migration around the region and worldwide. The need for clinical research targeting challenges affecting the practice of medical physics, adaptation of radiotherapy techniques and development of new cancer treatment cannot be over emphasised.

In Zambia, there are efforts underway to set up an organisation to solely propel the development of medical physics; dealing with several aspects stemming from career progression to continuous professional development (CPD). Such a body would have to work in collaboration with the HPCZ in the issuance of practising licences and malpractice.

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