RADIOTHERAPY INFRASTRUCTURE FOR BRAIN METASTASIS TREATMENT IN AFRICA: PRACTICAL GUILDELINES FOR IMPLEMENTATION OF A STEREOTACTIC RADIOSURGERY (SRS) PROGRAM

Purpose

Radiosurgery with the Gamma Knife system is the golden standard for the treatment of brain metastasis cases, however accessibility in many countries is limited. Modern radiotherapy has made this treatment possible using other equipment such as linear accelerator (linac)s and Cyberknife. The objective of this work was to explore the distribution of available radiotherapy equipment for brain metastasis treatment in Africa and provide practical guidelines to the establishment of an SRS Program.

Material and Methods

The IAEA's Division of Human Health's Directory for radiotherapy Centres (DIRAC), served as the primary source for the distribution of radiotherapy equipment throughout Africa. Data on megavoltage radiotherapy equipment for the 54 Africa countries were extracted from this database. Cancer incidence and brain metastasis assumption were made using data from the GLOBOCAN 2020 database and a country's income was assessed using the GDP per capita on the world economics database. Further literature search was also carried out on the price and availability of dedicated equipment for brain metastasis management in Africa in PubMed. All these searches were carried out in April,2023.

Results

There was increase in the number of brain metastasis cases. There were only two Gamma Knife machines in Africa. Three Cyberknifes; two in Egypt and one in Kenya and 432 other Mega-voltages units (66 cobalt-60s,366 linacs) distributed across the continent. The cost of a Gamma Knife machine could be up to US$7 million compared to that of a linac between $2.4 and $2.8 million and Cyberknife Between $3 and $5 million. A country's (GDP) per capita was a vital determinant of the number of these machines in countries which did not have any machines to ones which have at least one machine but did not account for the number in variability.

Conclusion

Access to radiosurgery treatment for brain metastasis with the Gamma Knife or Cyberknife is limited due to the low number of such equipment. With radiotherapy expansion and increase in linear accelerator number, it is likely that the continent will be able to increase its stereotactic radiosurgery treatment centers by implementing linac-based SRS following suitable guidelines. This will help provide comprehensive care to patients and promote quality of life.

Keyword: Stereotactic radiosurgery, Gamma knife, Cyberknife, Linac, brain metastasis

Introduction

Brain metastasis refers to the proliferation of cancer cells leaving another part of the human body to the brain. It is a common complication of advanced cancer and this happens when cancer cells move from the primary tumor and spread through either the bloodstream or lymphatic system to the brain[1]. Brain metastases can originate from various types of cancer, including lung, breast, melanoma, colon and kidney [1–3]. Africa comprises around 16% of the global human population and is recognised as the second-largest and second-most populated continent globally, behind Asia [4]. In Africa, the increasing cancer cases are likely to lead to an increase in patients with metastatic brain cancer. This has been projected to increase further by 2030[5].

The symptoms of brain metastasis vary depending on the tumor size and location. Symptoms include headaches, seizures, cognitive changes, weakness, balance problems, and changes in vision or speech [6, 7]. If a patient with known cancer develops neurological symptoms or if brain metastasis is suspected, imaging such as MRI,CT or PET scans are typically performed to confirm the diagnosis [8–10].

Options available for brain metastasis treatment may include surgical resection, radiation therapy with either whole-brain radiation therapy (WBRT) or stereotactic radiosurgery or both, systemic therapy and supportive care[11]. Among these treatment options stereotactic radiosurgery has been found to provide optimum clinical outcome [12, 13]. Many lower middle income countries, especially in Africa, use whole-brain radiation therapy with cobalt-60 technology for the management of brain metastasis because these treatment units are generally less expensive, and are easier to operate and maintain than linear accelerators (Linacs), Gamma Knife or Cyberknife [14, 15].

Stereotactic radiosurgery (SRS) is a type of radiation therapy that provides a very precise form of therapeutic radiation to treat lesions in the brain and spine [16]. SRS carefully directs several X-ray beams towards aberrant tissues without making an incision or opening [17–19].

Although access to this treatment modality for brain metastasis management is greatly expanding in the United States, Europe, Canada, and Asia, it is still restricted in many other regions of the globe, especially in Africa and South America [20]. This discrepancy is alarming since radiosurgery is a less invasive, highly successful method that might be very helpful in regions where open surgery may be expensive to provide treatment [21, 22].

Additionally, compared to these developed continents, epidemiologic data on cancer and brain metastases are substantially scarce and incomplete in low-income nations predominantly in Africa[21, 23, 24]. This in most instances can lead to an underestimation of number of brain metastasis cases and subsequently of the need for radiosurgery [22, 25, 26]. Although Gamma Knife is the golden standard equipment for treatment of brain metastasis, the advancement of modern radiotherapy has made treatment also possible with other equipment such as the Cyber knife and Linear Accelerators [27].

In view of this, the objective of this work was to explore the distribution of available radiotherapy equipment for brain metastasis treatment in Africa and provide practical guidelines to the establishment of an SRS Program.

Materials and Methods

A database of the Fifty-four (54) African countries was created. Figures on a country's population, gross domestic product (GDP) per capita, cancer cases as well as brain metastasis cases and radiotherapy equipment were considered. GDP per capita data were taken from the world economics database [28]. The Population by country was taken from the worldometer database [29] while figures on cancer cases for each country was taken from the GLOBOCAN 2020 database[30].

The IAEA's Division of Human Health's Directory for radiotherapy Centres (DIRAC),which is an electronic, centralised, and regularly revised directory of radiation facilities, served as the original source for the distribution of radiotherapy equipment throughout Africa[31]. Radiotherapy equipment data availability in Africa countries were extracted in April, 2023.A further literature search was also carried out in PubMed to also explore the number of dedicated equipment for brain metastasis treatment as well as linac distribution in Africa.

Estimates of number of brain metastasis

It is estimated 20 to 40 percent of cancer cases are likely to develop brain metastasis [30]. Using the GLOBOCAN 2020 data on cancer cases on each country in Africa, we calculated the number of brain metastasis by using an assumption of thirty (30) percent of the total number of cancer cases in each country.

Statistical analysis

Data entry and analysis were performed using Microsoft Excel and Statistical Package for Social Science (SPSS) version 26. A simple linear regression was used to correlate available number of equipment per assumed number of brain metastasis to GDP per capita in each country.

Results

Current status of radiotherapy facilities available for brain metastasis treatment in Africa

The literature search resulted in only two articles. From this search and the DIRAC database,239 radiotherapy centres were identified in 33 countries as seen in figure 1. There were only two Gamma Knife machines in Africa located in South Africa and Egypt [22, 32]. Three Cyberknifes, two in Egypt and one in Kenya [33] and 432 other megavoltage machines (66 cobalt-60 and 366 linacs) distributed across the continent mostly in the Northern and Southern belt on the Africa Continent as of April, 2023. Radiotherapy using linacs was seen in only 29 countries in Africa. The total number of machines available for the treatment of brain metastasis was 437 with the mean being almost 8. Linacs accounted for highest number of equipment available on the Africa continent for this treatment of brain metastasis. Egypt and South Africa has the highest total number of equipment representing 53.1% (232/437) as seen in figure 2 but only Egypt has the availability of all three machines for the treatment of brain metastasis cases.

In relation to these available machines, the Gamma Knife was found to be the most expensive within the price range of 5 – 7 million United States Dollars (USD) needed for purchase and installation, followed by the cyberknife knife 3 – 5 million USD and the least expensive being the linac 2.4 - 2.8 million USD (Table 1). Complete data on machine availability, GDP per capita, population and number of cancer cases were available for 48 countries out of the 54 representing 89.9%. GDP per capita data was unavailable for six countries namely Equitorial Guinea, Eritrea, Sao tome and Principe, Seychelles, Somalia and Djibouti. The number of people in Africa was almost 1.4 billion while the number of total cancer cases was 1,105,336 according to the Globoccan 2020 cancer data. Cancer data for Seychelles was not available. From this data, a thirty percent assumption for the number of brain metastasis was 331,600.8. The Average GDP per capita income was 8067.77.

Nigeria was the most populated country in Africa. The absolute number of cancer cases and assumed number brain metastasis cancer would have been thought to come from Nigeria but this was seen with Egypt representing 12.1%(134,632/1,105,336) and 12.2% (40389.6/331,600.8) for total cancer cases and assumed number of brain metastasis respectively.

Table 1: Total Cost and installation of Radiotherapy Machines for Brain Metastasis Treatment

Radiotherapy Machines for Brain Metastasis Treatment	**(Cost in USD million)**
Gamma knife	5 – 7 [34]
Cyber knife	3 – 5 [35]
Linear Accelerator	2.4 - 2.8 [36]

In comparison with a DIRAC 2012 data and literature, only one Gamma knife and no Cyberknife was in existence in Africa for brain metastasis treatment but there were 294 other megavoltage machines comprising of 89 cobalt-60 units and 205 Linacs. There have been 161 additional linacs installed and 23 cobalt-60 units decommissioned. This represent a 78.5% increase in the number of linacs installed and 25.8% reduction in the number of cobalt-60 units since 2012. Linac radiotherapy was now available in 29 out of the 54 countries, compared with 23 in 2012 [33].

It can also be noted that out of the 432 other megavoltage machines installed in Africa, majority of these could be located in lower middle income countries (282/432) as seen in Figure 1.

Table 2: Shows a distribution of the various variables of the 54 countries in Africa

COUNTRIES	NO. OF CANCER CASES	PROJECTED NO. OF BRAIN METS	NO. OF CYBER KNIFE	NO. OF GAMMA KNIFE	TOTAL NO. OF MV UNITS CO-60,LINAC		POPULATION	GDP PER CAPITA/$	TOTAL NO. OF MACHINES UNIT PER BRAIN METS	TOTAL NO. OF MACHINES
ALGERIA	58418	17525.4	0	0	2	35	45,606,480	12,997	0.002111221	37
ANGOLA	20327	6098.1	0	0	0	3	36,684,202	11,231	0.000491957	3
BENIN	6747	2024.1	0	0	0	0	13,712,828	5,329	0	0
BOTSWANA	2010	603	0	0	0	1	2,675,352	23,639	0.001658375	1
BURKINA FASO	12045	3613.5	0	0	0	0	23,251,485	3,352	0	0
BURUNDI	7929	2378.7	0	0	0	0	13,238,559	1,264	0	0
CAMEROON	20745	6223.5	0	0	2	1	28,647,293	5,379	0.000321363	2
CAPE VERDE	825	247.5	0	0	0	0	598,682	9,216	0	0
CENTRAL AFRICA REPUBLIC	2675	802.5	0	0	0	0	5,742,315	1,690	0	0
CHAD	8575	2572.5	0	0	0	0	18,278,568	2,529	0	0
COMOROS	609	182.7	0	0	0	0	852,075	4,089	0	0
CONGO (BRAZAVILLE)	2478	743.4	0	0	0	0	6,106,869	6,055	0	0
COTE D'IVOIRE	17300	5190	0	0	0	2	28,873,034	8,847	0.000385356	2
DJIBOUTI	765	229.5	0	0	0	0	1,136,455		0	0
DR CONGO	48839	14651.7	0	0	0	0	102,262,808	2,180	0	0
EGYPT	134632	40389.6	2	1	21	104	112,716,598	18,936	0.003094856	128
EQUITORIAL GUINEA	927	278.1	0	0	0	0	1,714,671		0	0
ERITREA	2408	722.4	0	0	0	0	3,748,901		0	0
ESWATINI	992	297.6	0	0	0	0	1,210,822	14,980	0	0
ETHIOPIA	77352	23205.6	0	0	1	2	126,527,060	3,690	0.000129279	3
GABON	1750	525	0	0	0	2	2,436,566	28,817	0.003809524	2
GAMBIA	1035	310.5	0	0	0	0	2,773,168	3,712	0	0
GHANA	24009	7202.7	0	0	2	3	34,121,985	8,940	0.000833021	5
GUINEA	7871	2361.3	0	0	0	0	14,190,612	4,503	0	0
GUINEA-BISSAU	1127	338.1	0	0	0	0	2,150,842	2,882	0	0
KENYA	42116	12634.8	1	0	2	15	55,100,586	6,930	0.00134549	18
LESOTHO	1876	562.8	0	0	0	0	2,330,318	3,807	0	0
LIBERIA	3552	1065.6	0	0	0	0	5,418,377	2,293	0	0
LIBYA	7661	2298.3	0	0	1	7	6,888,388	28,749	0.003480834	8
MADAGASCAR	20681	6204.3	0	0	2	1	30,325,732	2,604	0.000483536	3
MALAWI	17936	5380.8	0	0	0	0	20,931,751	2,112	0	0
MALI	14185	4255.5	0	0	0	1	23,293,698	4,226	0.00023499	1
MAURITANIA	3079	923.7	0	0	0	3	4,862,989	7,893	0.003247808	3
MAURITIUS	3050	915	0	0	2	1	1,300,557	27,147	0.003278689	3
MOROCCO	59370	17811	0	0	2	44	37,840,044	11,054	0.002582674	46
MOZAMBIQUE	25446	7633.8	0	0	0	1	33,897,354	1,901	0.000130996	1
NAMIBIA	3345	1003.5	0	0	1	1	2,604,172	12,898	0.001993024	2

NIGER	9787	2936.1	0	0	0	0	27,202,843	1,957	0	0
NIGERIA	124815	37444.5	0	0	2	7	223,804,632	9,333	0.000240356	9
RWANDA	8835	2650.5	0	0	0	2	14,094,683	3,390	0.000754575	2
SAO TOME AND PRINCIPE	151	45.3	0	0	0	0	231,856		0	0
SENEGAL	11317	3395.1	0	0	0	3	17,763,163	5,489	0.000883626	3
SEYCHELLES	0	0	0	0	0	0	107,660		0	0
SIERRA LEONE	4708	1412.4	0	0	0	0	8,791,092	2,956	0	0
SOMALIA	10134	3040.2	0	0	0	0	18,143,378		0	0
SOUTH AFRICA	108168	32450.4	0	1	3	100	60,414,495	19,331	0.003174075	104
SOUTH SUDAN	6312	1893.6	0	0	0	0	11,088,796	7,089	0	0
SUDAN	27382	8214.6	0	0	6	4	48,109,006	7,089	0.000973876	10
TANZANIA	40464	12139.2	0	0	2	5	67,438,106	4,181	0.000659022	7
TOGO	5208	1562.4	0	0	0	1	9,053,799	3,209	0.000640041	1
TUNISIA	19446	5833.8	0	0	11	14	12,458,223	14,154	0.004456786	25
UGANDA	34008	10202.4	0	0	2	1	48,582,334	3,320	0.000294048	3
ZAMBIA	13831	4149.3	0	0	2	1	20,569,737	5,609	0.000723014	3
ZIMBABWE	16083	4824.9	0	0	0	1	16,665,409	4,275	0.000207258	1
					66	366				
TOTAL	1105336	331600.8	3	2	432		1,458,571,408	387253	0.042619669	437
STANDARD DEVIATION	30271.73	9081.52	.302	.19	22.83		39066864.34	7291.51	00121955870	23.21
MEAN	20469.19	6140.76	.06	.04	8.00		27010581.63	8067.77	.0007892531	8.09

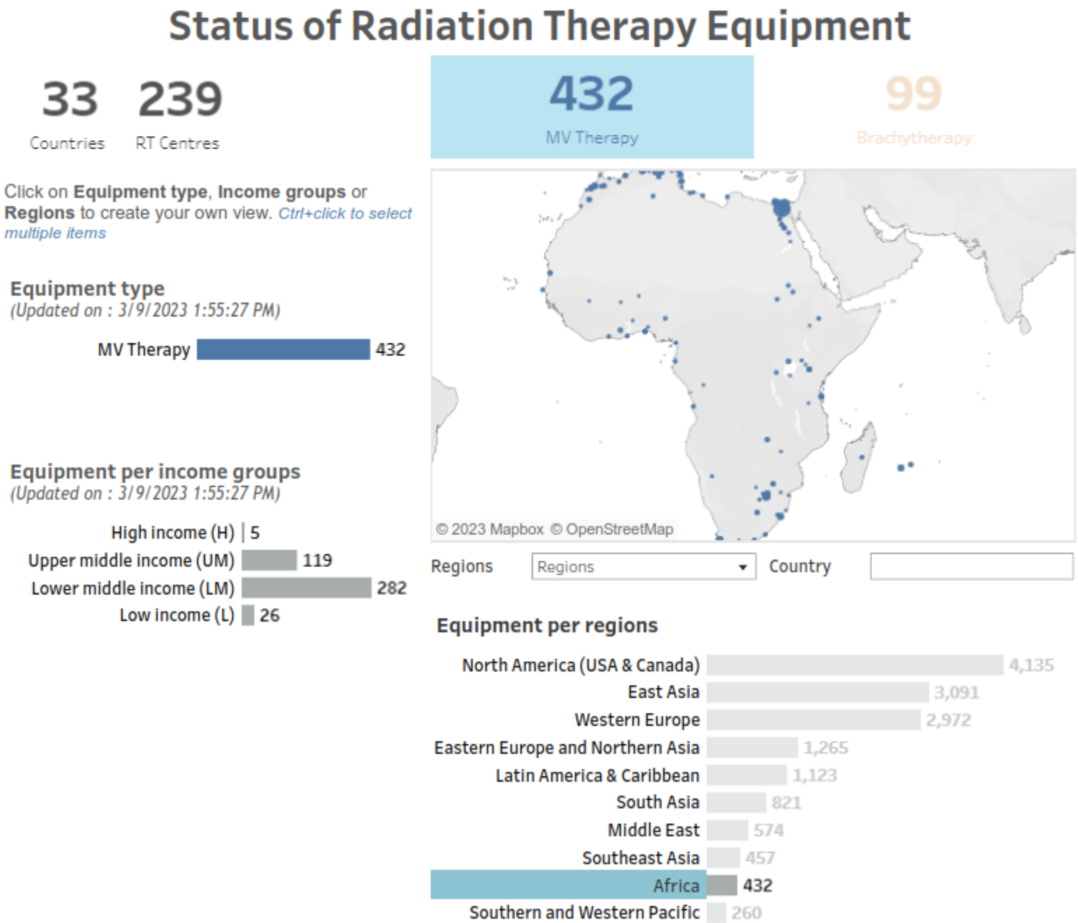

Figure 1 illustrates the current status of radiation equipment throughout the African continent. The figure shown in the aforementioned sourced from dirac.iaea.org

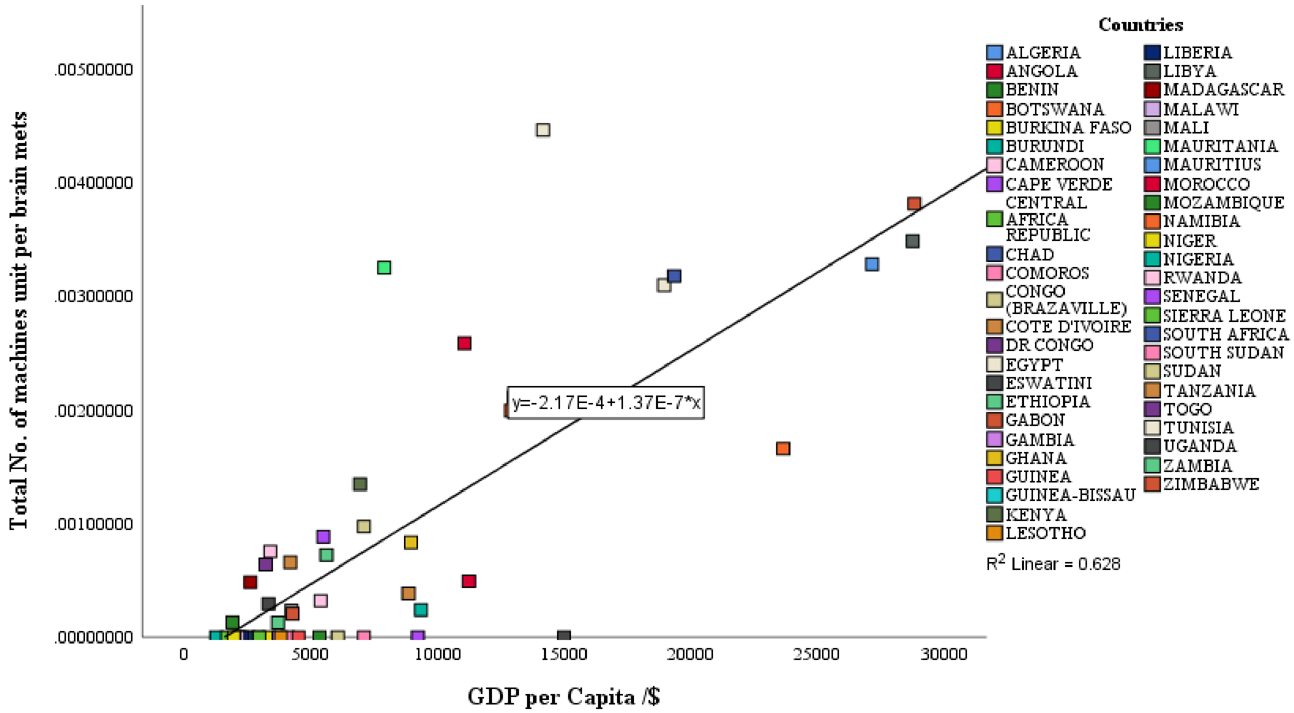

Figure 2 above shows a scatter plot of total number of machines per projected number of brain mets by GDP per capita ($) for African Countries.

The availability of these machines for the treatment of brain metastasis cases was analysed by the GDP per capita of each country as seen in figure 2 and table 2. A significant disparity in median income was observed between nations possessing radiation therapy capability and those without such infrastructure. Median GDP per capita among countries without any radiotherapy capacity was US$3352 (US$1,690– US$14,980), compared with US$7893 (US$1,901– US$28,817) for countries with at least one of the machines for radiation therapy treatment. Despite the high GDP per capita of Eswatini, it had no radiotherapy equipment installed compared to Mozambique which has a low GDP per capita but has one machine installed. Gabon was found to have the highest GDP per capital but despite this, the number of available machines installed is less than that in Egypt which has the highest number of machines. The number of total machines units per brain mets cancer cases was correlated with GDP per capita ($r^2=0{\cdot}628$). The linear regression model therefore accounts for some variations. This therefore suggest that other factors might explain variability in the availability of the number of these machines in each country.

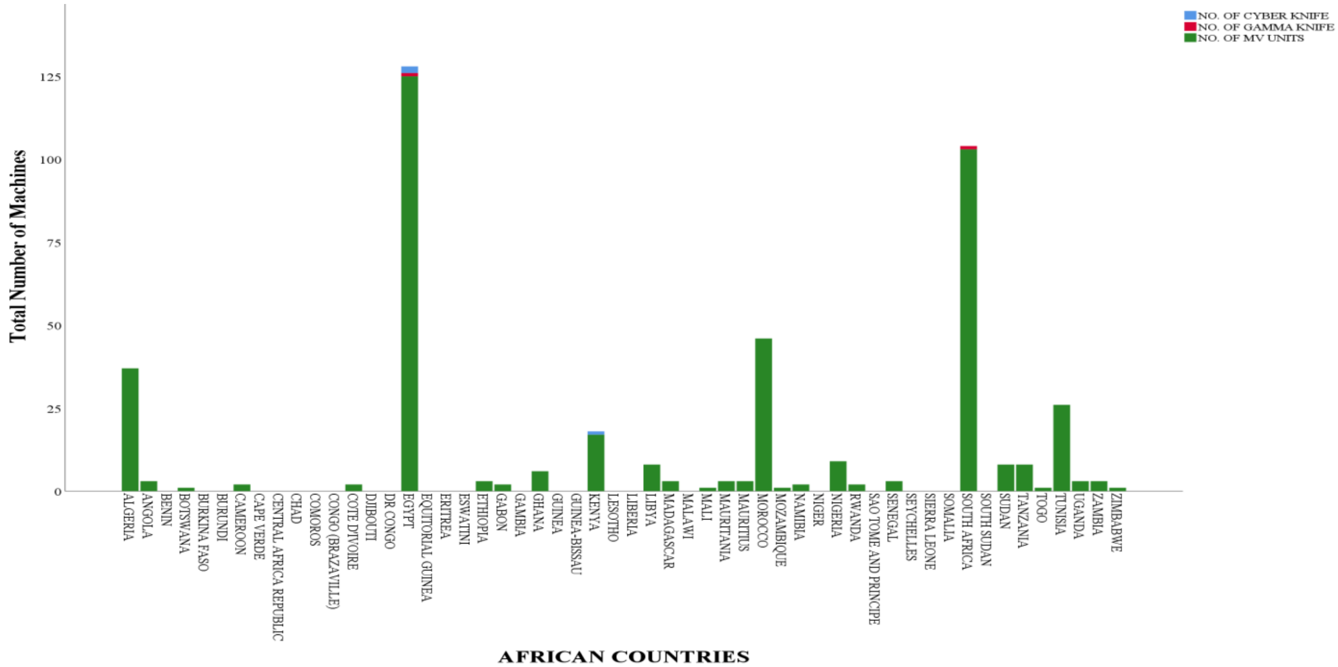

Figure 3 above illustrates a stacked bar graph of Total Number of Machines per African Countries

Discussion

This study explored the distribution of available radiotherapy equipment for the treatment of brain metastasis in Africa and provided practical guidelines to the establishment of an SRS Program. There is an increase in the number of cancer cases, hence an increase in the number of brain metastasis. Radiotherapy is one of the key treatment modalities for cancer management [23]and as such stereotactic radiosurgery play a key role in the management of brain metastasis [37]. When comparing the present state of affairs in Africa to the prior assessment from 2012 in term of machine distribution, we saw that there has been improvement in terms of absolute radiotherapy capacity [33]. Africa now has two Gamma knifes, three cyberknife,366 linacs and 66 cobalts units. However, the increase in the number of these machines have not kept up with the need for radiotherapy and the growing number of cancer cases. For brain metastasis and the plethora of other cancers for which radiotherapy is part of their mainline treatment, this is likely to lead to an increase in mortality [38–40].

The total availability of these machines in the United States and Europe were in excess of four thousand and three thousand respectively[31]. From this study, linacs accounted for highest number of the total number of machines available representing 83.8% (366/437). This increase may be due the expansion projects going on in many countries to improve accessibility. The reduction of cobalt-60 units may be due discontinuation in the manufacture of cobalt-60 units, lack of spare parts, lower clinical outcomes and security concerns. In many developed and high income countries, Cobalt-60 teletherapy machines are no longer used for treatment [41].

The limited number of Gamma knife and Cyberknife machines (2 Gamma Knife,3 Cyberknife) on the continent may be as a result of the high cost associated with the purchase and installation of this machines. With many of these African countries deemed to have lower GDP per capita, it means the purchasing power to acquire these machine is low [28] . Another factor could be the low number of trained professionals needed. The lack of dedicated stereotactic radiosurgery (SRS) installations in Africa may be attributed to the insufficient number of neurosurgeons, radiation oncologists, and physicists in the region, which poses substantial challenges to addressing this issue. The aforementioned obstacles are further compounded by the financial implications associated with maintenance and repairs, necessitating costly maintenance contracts with the manufacturers [25].

Given this perspective, it is plausible that a nation's economic factors significantly contribute to this inequality owing to the substantial expenses associated with Gamma Knife and Cyber technologies. Numerous instances have shown that regions in the United States and Europe possess a budget that exceeds that of Africa and the Middle East by a factor of at least ten.[22]. Equipment availability are strongly correlated with national income, suggesting that money determines availability and is a need for access. In the light of this, low-income countries without any radiotherapy machine require strategies to incorporate it into their national health care programmes or partner with other organizations in this regard[42, 42, 43]. One such organization is the IAEA, International Atomic Energy Agency. The IAEA offers several initiatives designed to aid Low and Middle-Income Country (LMIC) Member States in obtaining access to radiation therapy. These programmes include assistance in the decision-making process for choosing and procuring radiotherapy equipment, as well as facilitating machine setup and training [44].

Gamma Knife has historically been the gold standard equipment for stereotactic treatment for brain metastasis [39, 45, 46], the higher cost of its installation has made it difficult to assessed by low and middle income countries mostly in Africa. With over 1.4 billion people living in Africa, the continent has no linac-based SRS installations [45]. Linacs could be reported as being dominant on the Continent according to this study hence linac-based SRS has the capability to employed for brain metastasis patients as compared to Gamma Knife and Cyberknife. Supposedly half the 366 linac could be enhanced into linac-based SRS machine, this could translate into better management and accessibility to this form of treatment.

A recent study by Dean et al, reported that there were approximately 428 dedicated machines for SRS in the United States. Out of this, linac-based systems were the most popular and accounted for 39%, followed by CyberKnife 35% and Gamma Knife 26% [47]. Europe has also seen comparable patterns in the increased utilisation of linear accelerator (linac)-based stereotactic radiosurgery (SRS) systems relative to gamma-based SRS systems [15].

Linear accelerators (linacs) that are specifically designed for stereotactic radiosurgery (SRS) have been shown to provide clinical results that are comparable to those achieved with Gamma Knife radiosurgery. The comprehension of access to LINAC-based radiosurgery has significant significance because of its potential for wider implementation in settings with low resources. Additionally, LINAC-based radiosurgery exhibits greater versatility as it may be used for administering various kinds of radiation therapies.[46]. Moreover, current research indicates that the cost per patient for Gamma Knife therapy is much higher compared to LINAC-based treatment. This holds true for scenarios when LINAC systems are used extensively, as well as when they are solely employed for radiosurgery [21, 48].

Whiles some countries in Africa have plans of acquiring dedicated machines for SRS, others plan to equipped their existing linac into linac-based SRS System. Mauritius has advanced with its plans to acquire a cyberknife machine according to the Mauritian Government National cancer control programme 2022-2025[49].Ghana have plans to equip their linacs to deliver a linac-based SRS.

In an effort to lower initial investment and increase accessibility in low-resource countries, at least one company, ZAP Surgical Systems, Inc., in San Carlos, California is developing a self-shielded 2.7-MeV linac system dedicated to SRS under the brand name Zap-X. This system is advertised as not typically requiring a radiation bunker [45].

Stereotactic Radiosurgery: Practical guidance for implementation

Looking at the wide range of benefits of stereotactic radiosurgery in the care, management and treatment of intracranial metastatic tumors [39, 40], its implementation in our various clinical facilities would be of great importance and help. However, launching a quality stereotactic radiosurgery program requires a lot of great thinking and ideas from clinicians of various multidisciplinary fields including neurosurgery, radiation and oncology and diagnostic medical imaging [34]. All these must be done to ensure the smooth and successful running of the program to achieve its purpose, target and goals.

The following guidelines can be looked at when implementing a smooth stereotactic radiosurgery program.

1. Goals establishment

The zeal, passion and drive to roll out a comprehensive stereotactic radiosurgery program demands a carefully and systematically scrutized and thorough analysis of resource needs and financing, a confirmed set of goals, a mission and vision statement, together with how feasible the program is and will be. This evaluation requires a multidisciplinary deliberation, sharing and thinking through of the ideas with enthusiastic set of stakeholders made up of institutional and management leaders and board members, clinical leaders, primary care providers, referring physicians, and allied health professionals. The objectives of the program should be known, the perceived needs and as such reasons for the program and the target group of people who the program when successfully launched will benefit amongst others should be known [15, 50].

2. Availability of well-trained, highly skilled and professionally-acknowledged personne.

The establishment and launching of a smooth SRS program start with the assembly of a specialized team of multidisciplinary professionals. The team should be well trained, highly-skilled, professionally-acknowledged by the regulatory and professional bodies with high credentials in every aspect of radio-surgical planning and treatment delivery procedures. This team should at least comprise, an oncologist (radiation, surgical or medical), a clinical medical physicist, radiation therapists or nurses with experience in radiosurgical oncology. This team will see to the effective running of the program by properly taking care, managing and treating patients who are in need of stereotactic radiosurgery [51].

3. Financing the program

Financing and resourcing are vital ingredient to the overall success, smooth and safety implementation of the SRS program [48]. There must be a high institutional and management commitment to finance and provide all that is needed to start the program and not only to start but to keep the program running smoothly. There must be an ever-ready financial commitment on the part of the management team of the institutions to provide all the right, proper and best oncological equipment needed by the SRS team for their operations in the facility [52].

4. A careful analysis of the target group

The target group here is our patient population. Each country or institution must carefully analyze its patient population, cancer cases and understand the probable influence of already existing treatment techniques. The economic status of the target group must be factored in as well. Will the patients be able to afford the costs involved? Will the patients go in for SRS or go in for other existing techniques such as IMRT or WBRT? After all these have been answered, the implementation of the program can then move to the next level [15, 51].

5. Procurement of the right equipment

The right equipment is an equally important as providing resources and finances for the program. The type of equipment, the work rate, the effectiveness and efficiency of it, the model, the brand, the manufacturing company and their track record in the business of manufacturing oncological machines, the operation of it amongst others must be factored in. Since SRS is a complex technique, the right machines must be procured so as to ensure the smooth running and operation of the program in the facilities [45]. The financial investment required for the commencement and implementation of a linac-based system is significant. This includes the procurement of a linac that is equipped with kilovoltage imaging capabilities or the necessary modifications to enable such capabilities. Contemporary treatment planning systems are equipped with sophisticated dose calculation algorithms and state-of-the-art imaging technologies like a computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography-computed tomography (PET-CT). Additionally, these systems include immobilisation devices and physics quality assurance (QA) equipment, including those specifically designed for small-field dosimetry. Water phantoms and plan QA devices are also often used in this context. Prior to initiating a clinical programme, Task Group 100 of the American Association of Physicists in Medicine (AAPM) suggests that the multidisciplinary team of healthcare professionals engaged in patient care should develop a process map outlining the specific treatment procedure. Additionally, they should perform a failure modes and effects analysis for each individual step of the process, and establish a quality management programme based on risk assessment [34].

6. The availability and establishment of infrastructure

A proper layout system and a good site system is needed before implementing the SRS program. The potential implementation of bunker modifications, such as the building of additional vaults should be considered A good layout is needed to house the machines, the waiting patients to be attended to, the SRS team working in the field and more importantly to safeguard and protect the staff, patients and general public from radiological exposures [51].

7. Maintenance requirements and training needs

Launching and implementing the SRS calls for high maintenance needs and training needs. Regarding the training, the team must have some equipment training from the manufacturers of the equipment. This will help them in the day-to-day operation of the machines. Apart from the equipment training, clinical trainings, workshops and seminars are required. Short online clinical courses can be undertaken by members of the team in order to ensure that they are always abreast with the current and modern trends of patient care, management and treatment as far as SRS is concerned. Maintenance has always been a challenge especially in Africa. Daily, weekly, and monthly quality assurance checks must be done always on these machines. All errors noted during quality and routine checks must be properly documented and stored and reported to the manufacturing team of the machines for immediate resolutions[46, 53, 54].

8. Information technology needs

The world is a global village now and almost everything revolves around computers and internet. These advanced oncological programs are not only person or facilities related. They come along with a high IT demand. These include, installation and configuration of powerful computer systems, setting up of powerful internet connections, integration and networking into already existing hospital and general cancer programs networks, creation of the PACS and DICOM systems for the import, export, and retrieval of images over the internet from one locality to another and sometimes from one city to different cities across the world to help with the diagnoses, care, management and treatment of patients[50, 53].

Stereotactic Radiosurgery: The need for it be covered in the educational/residency curricula.

Stereotactic radiosurgery (SRS) is an important field that is growing in significance. There is a need for targeted training in SRS for all students and resident of radiation oncology team members involved in the SRS process [55, 56]. Including radiosurgery SRS in the educational/residency curricula can provide several benefits, including:

1. Addressing gaps in knowledge and competency among residents/students: Surveys have shown that neurosurgery residents and medical physics intern possess gaps in SRS knowledge and procedural competency that have persisted [56]. For instance, the University of Rochester's radiation oncology residency programme includes a structured core rotation that allows residents to work one-on-one with an expert in SRS[57]. The flexible curriculum of the medical physics residency programme at the University of Maryland School of Medicine allows residents to maximise their learning experience in the field of SRS throughout their two years of training [58]. This same form of modification to the curriculum can be adopted to help address these gaps.

2. Improved patient outcomes: Compared to traditional open surgery, patients who undergo SRS experience equal or superior success, with fewer complications and a faster recovery[12, 59]. By including SRS in the curricula, residents can learn about this advanced technology and how it can benefit their patients.

3. Keeping up with the growing field: As the field of brain stereotactic radiosurgery (SRS) continues to grow, so will the need for a comprehensive evidence base [15, 56]. By including SRS in the curricula, residents can stay up-to-date with the latest advancements in the field.

4. Multidisciplinary team approach: A quality SRS program requires a multidisciplinary team. By including SRS in the curricula, residents can learn about the importance of working collaboratively with other healthcare professionals to provide the best possible care for their patients [34].

Limitations

There are some limitations inherent in our work. The comprehensiveness and reliability of the DIRAC statistics are subject to ambiguity owing to the optional and self-reported character of the database. Furthermore, Africa exhibits a very dynamic scenario characterised by frequent installations, annual occurrences, and regular adjustments or replacements of equipment. The accuracy of the GLOBOCAN 2020 estimates for existing and predicted brain metastasis cancer cases may be compromised due to the continuous establishment of population-based cancer registries across Africa and also the 30 percentage assumption made. The lack of complete data for the mentioned six countries might affect holistic discussion on the Africa Continent.

Conclusion

With the steady increase in brain metastases cases and the number of linacs, the adoption of stereotactic radiosurgery as the modality for the management and treatment of brain metastases will improve the quality of life, with a decreased rate of reoccurrence and a high local tumour control. The implementation of linac-based SRS can make for a smooth running of an SRS program. Though the launching and implementation of the program may also be challenging but a careful analysis of the guidance and a successful execution will go a long way to be of great help in managing metastatic brain tumors in the future.

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