Burden and Pattern of Cancer in the Sudan, 2000-2006

**Mohammed Elimam Mohammed[1], Ammar Mohamed Hassan[2],
Hala Ahmed Abdelhadi[2], Mohamed Gamaleldin Elsadig[2],
Dalal Mohamed Adam[2], Khalid Elmamoun[2], Rania Hamid[2], Hiba Elias[2],
Mohamed Abdallah[2], Zaki Abdelkarim[2], Nasr Eldin Elwali[3]
and Sulma Ibrahim Mohammed[4*]**

[1]*Department of Biochemistry, Faculty of medicine, Sudan.*
[2]*Sudan Atomic Energy Commission, Sudan.*
[3]*Gezira University, Wadmadani, Sudan.*
[4]*Department of Comparative Pathobiology and Purdue University Center for Cancer
Research, Purdue University, West Lafayette IN, USA.*

Authors' contributions

*All authors concur with the submission. All authors of this protocol have made a substantial
contribution to its conception and design, data collection, analysis and interpretation. All
authors read and approved the manuscript.*

Original Research Article

ABSTRACT

Aims: The aim of this study is to determine the number of newly diagnosed cancer cases and their distribution in two cancer-care providing facilities in Sudan.
Study Design: This is a retrospective descriptive study.
Methodology: Data was retrieved from patients' records that were diagnosed and treated at the Radiation Isotope Center in Khartoum (RICK) and National Cancer Institute at Wadmadani (NCI -UG) in Sudan over the period between 2000 and 2006 and then statistically analyzed.
Results: A total of 26652 cancer cases were retrieved with a noticeable increase in numbers from year 2000 to 2006. The maximum cancer number was observed in 45-64 year age group in both male and female patients with a male to female ratio of 1.3:1.0. The most common cancer sites for females were: the breast (29.3%), cervix uteri (8.2%), leukemia (7.2%), ovary (6.8%), and esophagus (5.9%) and for males: were

---

*Corresponding author: Email: mohammes@purdue.edu;

prostate (7.6%), followed by leukemia, (7.0%), NHL (6.8%), esophagus (5.4%) and bladder (4.4), while leukemia (25.2%), NHL (12.4%), lymphoma (10.8%), retinoblastoma (6.6%) and brain tumors (3.3%) dominated in younger patients (<14 years old).
Conclusions: This study provided some knowledge about the cancer situation in two institutions providing cancer care in Sudan that may draw attention of policy maker and aid in formulating appropriate cancer-control strategies in the country.

1. INTRODUCTION

Cancer is a global health problem. It is among the three leading causes of death in the developing world. According to the World Health Organization's recent projection (2010), cancer caused about 7.6 million deaths in 2005, accounting for 13% of death worldwide and it will result in about 84 million deaths by year 2015. About 72% of cancer deaths in 2008 occurred in low- and middle-income countries. In Africa, 650,000 people of estimated 965 million are diagnosed with cancer annually and lifetime risk of dying from cancer in African women is two times higher than in women living in developed countries [1].

Furthermore, the health system in Sudan mainly focuses in communicable diseases with less attention given to non-communicable diseases and their prevention. Therefore, the burden of cancer in Sudan is not known. Reasons for that are many and include the facts that large proportions of the population never seek professional medical care and resource deficiencies that ranged from scarcity of trained health care workers, inadequate health care budget, insufficient diagnostic facilities, and until recently, lack of national population-based cancer registry.

There are two sources of cancer data in Sudan; Radiation and Isotope Center in Khartoum (RICK) located in the national capital Khartoum, Khartoum State, and the National Cancer Institute of the University of Gezira (NCI-UG) in Wadmadani, capital of the Central State. Both centers are located in the densely populated areas of the Sudan. According to data published by Hamad [2] in 2000, cancer is the third leading cause of death in Sudan hospitals after malaria and viral pneumonia. Cancer accounts for 5% of all deaths while malaria and viral pneumonia contribute 19.1% and 6.1%, respectively [2].

The fact that data on cancer in Sudan is scarce and because of the lack of the national-population-based cancer registry, age adjusted cancer incidence and mortality were not yet determined for the Sudanese population. Most of the published work was hospital-based and limited to certain institutions. This manuscript describes the cancer cases seen in RICK and at NCI of University of Gezira for the period 2000-2006. In addition, we will attempt to examine the types of cancer, gender and age distribution taking into account the limitations mentioned above regarding factors that may contribute to inaccurate reporting.

2. MATERIALS AND METHODS

2.1 Health Facilities in Sudan

During the study period, Sudan was recognized as the largest country in the African continent with a total area of 966,710 square miles, making the country slightly larger than one-quarter the size of the United States. Sudan is divided into 26 states and districts with varying number of population densities (Fig.1). States' Ministries of Health, Armed forces, Universities, Police and private sector collectively, in an uncoordinated manner, provide health services to the people of Sudan. The public sector health services in Sudan are organized at three levels primary, secondary and tertiary. The states' general hospitals are the referral centers for the entire state. Specialized centers and Khartoum General Hospital, located in capital Khartoum, constitute the tertiary level (Federal ministry of health web site). RICK and NCI-GU are the only two specialized cancer centers providing chemotherapy and radiotherapy services for all 26 states. Treatment is offered free for cancer patients. After exhausting all the medical attempts for treatment at the primary and secondary care facilities as well as local healers, patients are referred to RICK or NCI-GU depend on the proximity to the patient's resident.
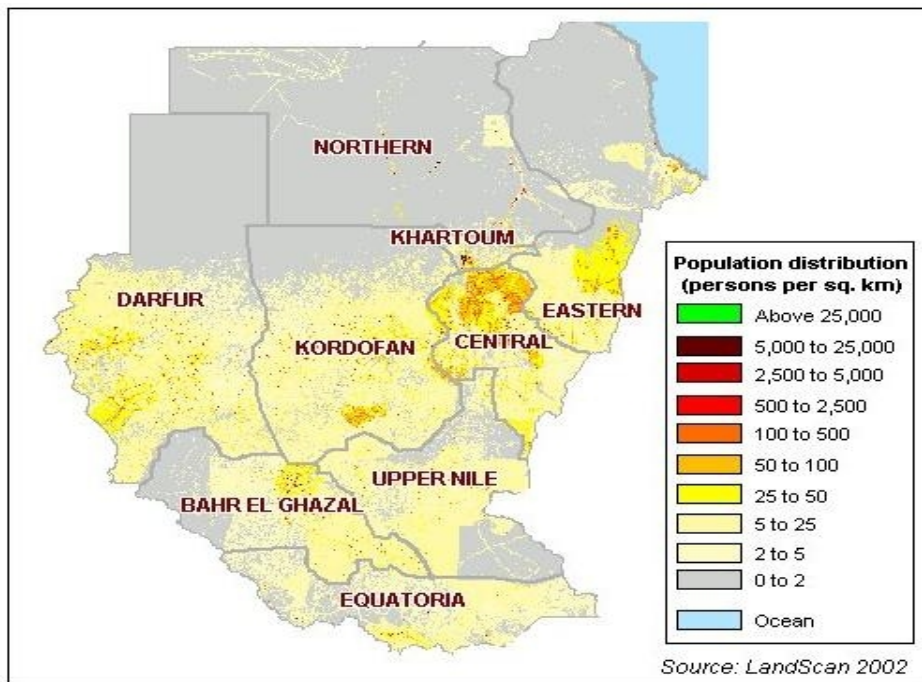

Fig.1. Sudan population density map

In addition, Sudan has a private health sector consisted of medical practitioners, small clinics, hospitals, and diagnostic laboratories services. Patients who can afford it only frequent these services. Health insurance not offered in Sudan and people depend on governmental assistants or religious charities. However, majority of patients diagnosed with cancer, if not all, end up at RICK or NCI-UG for further diagnosis or treatment (chemotherapy or radiotherapy treatment).

2.2 Study Design, Sites and Data Collection

As mentioned above, there were only two sources of cancer data in Sudan, RICK and NCI-UG. RICK located in Khartoum State (population 5,274,321; 2008 est.) and NCI-UG is located at Wadmadani, capital of Gezira State. The Gezira State is the second largest state with an estimated population of about 3,575,280 (2008 est.). The NCI-UG provides cancer care for patients from Gezira State as well as the surrounding states in the central region of Sudan.

Cancer cases were abstracted from patient records in these two centers from clinical, histopathological, cytological, hematological, and treatment records. Surgeries are usually performed at the Khartoum and Wadmadani teaching hospitals after which patient are followed up and treated at the two mentioned centers. No palliative care is provided by these two centers at that time. The study was approved by the Sudan Atomic Energy Commission at Khartoum.

2.3 Population

The Sudanese population in 2003 was 38,114,160 (39,154,490; 2008 est.). Median age is 17.5 years. National population data for population at risk is shown in Fig. 2.
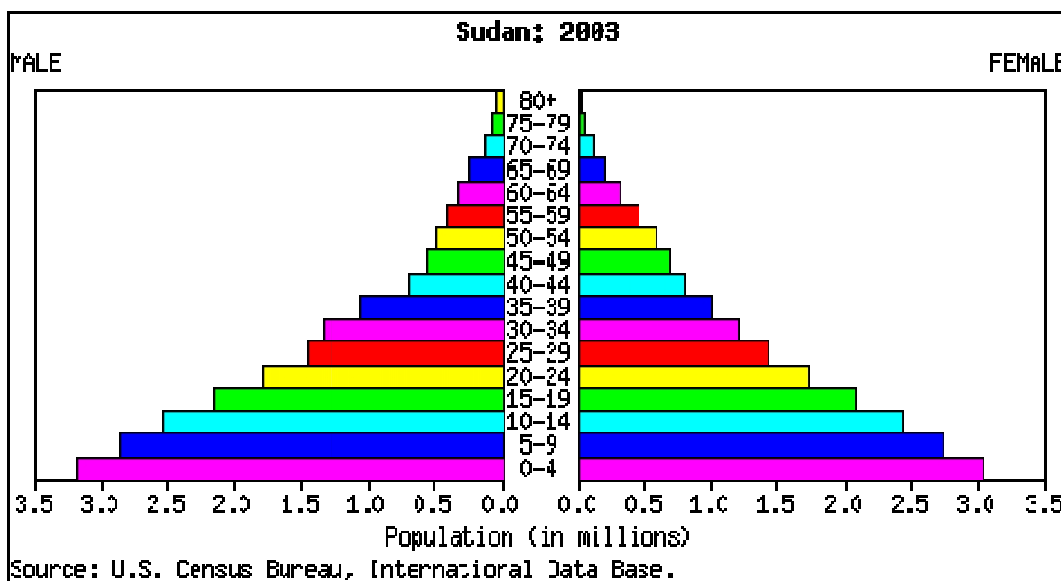

Fig. 2. Sudan population pyramid 2003

2.4 Data Analysis

Abstracted data from patient records at RICK and NCI-UG were checked for accuracy and duplication. Cases diagnosed by all means which include morphologically (histopathologically and cytology), clinical, and clinical investigations. All cases from all of Sudan are included in the analysis. Data was tabulated and analyzed using SPSS version 16, for age, gender, tribal affiliation, and most common cancers.

3. RESULTS

Cancer patients visit RICK and NCI-UG from all the 26 states of the Sudan. For the period from the First of January 2000 to 31 of December 2006, 26,652 new cancer cases were seen at either RICK or NCI-UG. The total newly diagnosed cancers in NCI-UG were 3,477 cases compared to 23,175 newly diagnosed cancers in RICK. In general, the number of cancer diagnosis increased from 2,863 in year 2000 to 5,110 patients in year 2006. There were 2,247 (78%) cases increase during those 6 years, (Fig. 3).
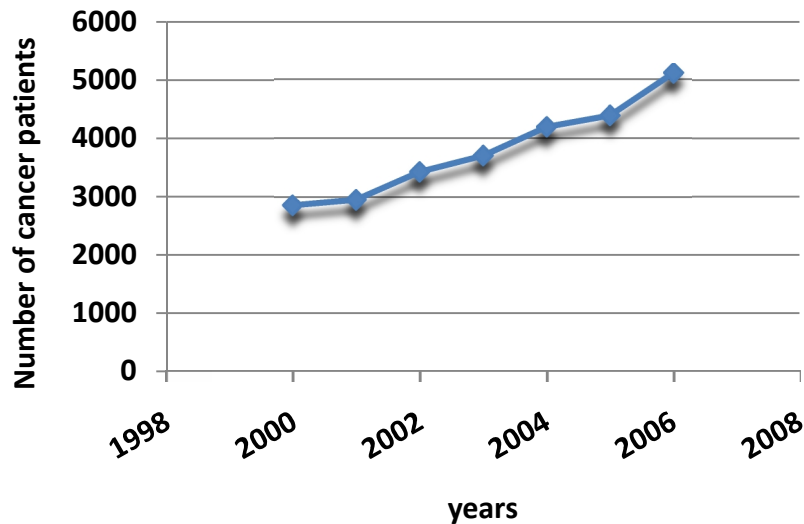

Fig. 3. Number of cancer cases registered at the RICK and NCI-UG during 2000-2006

Sudan is divided into 26 states, however, in this study Sudan was divided into six study regions. Each study region consisted of one or more states. The regions description was as follow: (1) Northern States region, consisted of Northern and River Nile States; (2) Khartoum Region, consisted only of Khartoum State; (3) Central region comprised of Gezira, white Nile, Blue Nile and Sinnar States; (4) Western region made of South, and North Kordofan and South, North and West Darfur States; (5) Eastern region consisted of Red sea, Al Gedarif and Kasala States; (6) Southern region made of all the states of the south. Of the newly diagnosed cases 2899 (10.9%) were from the Northern region; 2038 (7.6%) cancer patients from Eastern region, 3966 (14.9%) from Western states, 9294 (34.9%) from Khartoum State, 7954 (29.8%) from Central states, and 501 (1.9%) from Southern states (Fig. 4). The majority of patients belong to Khartoum and Central states.

In Sudan, there are more than three hundred tribes including Danagla, Gulyean and Shygea in the north; Bija in the east; Kababish, Hamar, Nuba, Baggara and Fur in the west; Dinka, Newir, and Skeluk in the south. Gulyean, Shygea, and Danagla had more cancer cases than any other tribes, 16.3%, 6.6%, and 5.3%, respectively.
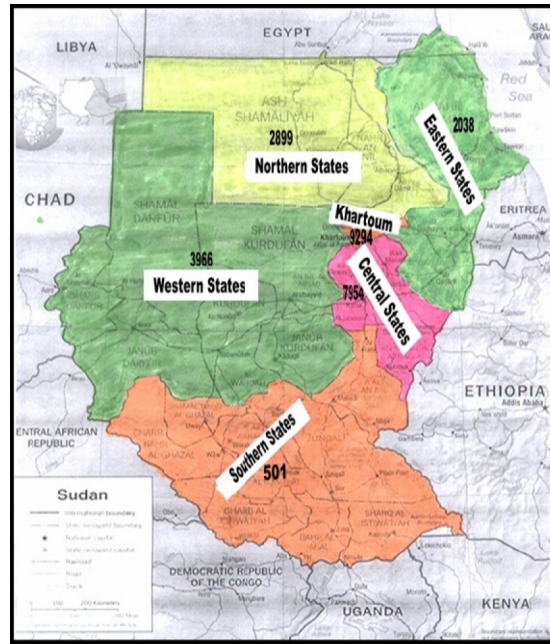
Fig. 4. Sudan map, the study regions and the number of newly diagnosed cancer cases in each study region

Fig. 5 shows cancer distribution according to age. The maximum number of cancer cases were seen between age 44-65, about one third of cancer patients were between age 15-44 and one fourth were older than 65.
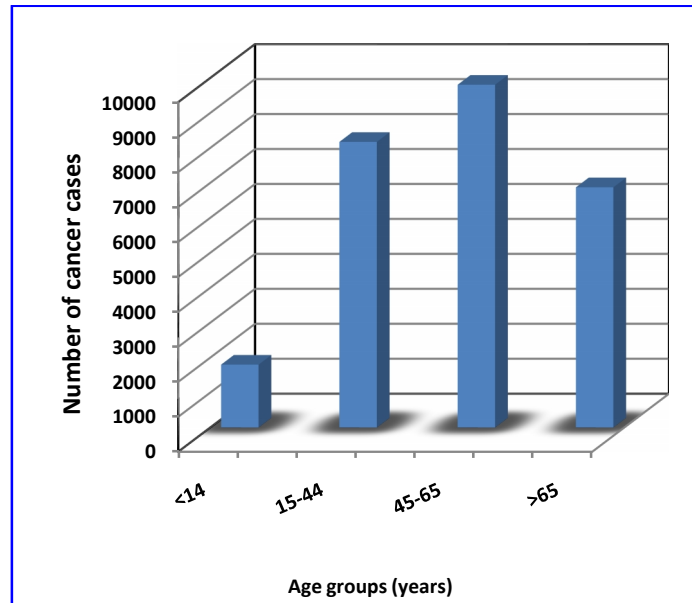

Fig. 5. Diagnosed cancer cases according to age groups

3.1 Common Site of Cancer in Sudan

Of the all 26,652 new cancer cases registered between 2000 and 2006 in both sexes, the top five cancers were cancer of the breast 4652 (17.5%) followed by leukemia 2282 (8.6%), cancer of the esophagus 1426 (5.4%), non-Hodgkin lymphoma 1336 (5%), and cancer of the cervix 1139 (4.3%) (Fig.6). Of the 13933 new cancer cases among females (Fig. 7) registered during the period 2000 and 2006, the top ten cancer were cancer of the breast, which was the most common accounting for 4085 (29.3%) of all cancer, followed by cancer of the cervix 1136 (8.2%), leukemia 1000 (7.2%), ovary 949 (6.8%), esophagus 825 (5.9%), NHL 385 (2.8%), thyroid 349 (2.5%), stomach 301 (2.2%), uterus 250 (1.8%), bladder 231 (1.7%) and other cancer accounting for 4422 (31.7%). In males, the top ten cancer among 10911 registered patients in the same period (Fig.7), prostate cancer was the most common 833 (7.6%), followed by leukemia 761 (7.0%), non-Hodgkin lymphoma 742 (6.8%), esophagus 589 (5.4%), bladder 476 (4.4%), rectum 317 (2.9%), stomach 306 (2.8%), larynx 263 (2.4%), colon 220 (2.0%), lymphoma 212(1.9%) and other cancer accounting for (56.8%).
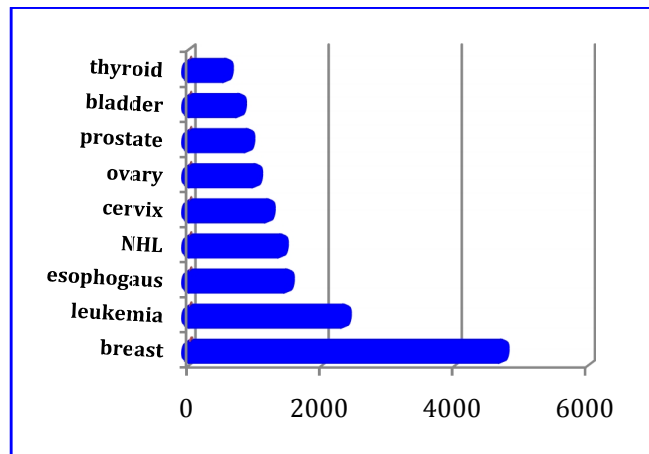

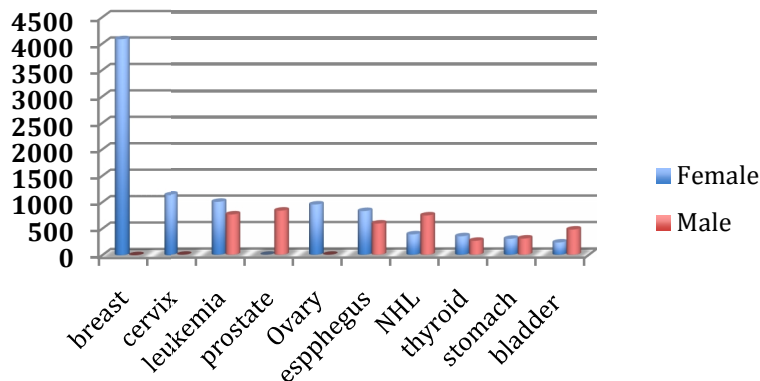**Fig. 6. The top most common cancer by site, in Sudan 2000-2006**

Fig. 7. Most common primary cancer sites by gender in Sudan: 2000-2006.

In children of both sexes, age 0-14 years (Fig. 8), the top ten cancer among 1808 registered patients during the same period, the leukemia was the most common cancer accounting for 456 (25.2%) of all children registered followed by non-Hodgkin lymphoma 225 (12.4%), lymphoma 196 (10.8%), retinoblastoma 119 (6.6%), brain tumors 110 (6.1%), Wilmstumors 60 (3.3%), eye tumors 52 (2.9%), osteosarcoma 47 (2.6%), ovary 15 (0.8%), stomach 9 (0.5%), and other tumors 519 (28.7%).
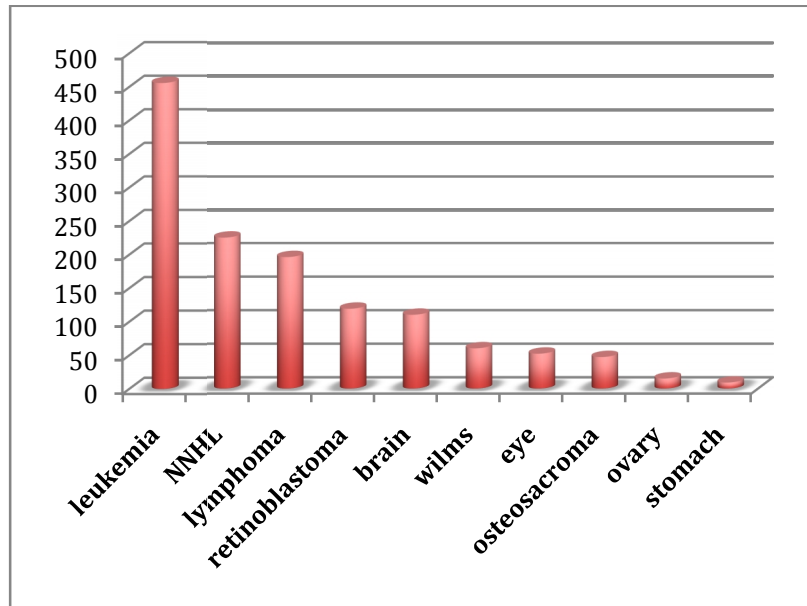

Fig. 8. Top ten-cancer sites in Children in Sudan 2000-2006

4. DISCUSSION

This descriptive hospital-based study demonstrated that cancer is an important public health problem in Sudan. The study showed that cancer cases were increasing in the Sudan cancer care providing facilities. The number of diagnosed cancer cases at RICK and NCI-UG at the end of the study period, year 2006, was almost double that of newly diagnosed cancer cases in year 2000. The reasons for the increase in cancer cases probably, due to the newly established Gezira cancer institute at Gezira State and possibly a reflection of the increase in population sizes in these states. The population in Khartoum in 2006 (7,253,102) was almost double of that in 2000 (4,700,000). In addition, this increase might be due population awareness of seeking treatment at health institutions. Both cancer centers cater to urban populations. However, this increase does not reflect the actual number of cancer cases in Sudan as poverty, crowded public transportations and cost of doctor fees and medicine contribute to patients seeking alternative treatment before pursuing treatment at proper cancer institutions. In addition, patients seek medical attention at later stage of the disease that is only amenable to palliation; therefore, patients were not referred to cancer specialized institutions and were not documented even in hospital-based records.

As seen from the geographical distribution of cancer cases Khartoum and Gezira states had more cancer cases diagnosed than other states. This could be attributed first; to the higher population densities and second the proximity of cancer treatment facilities such as RICK and NCI-GU in these two states. Most Sudanese population either do not know or do not have residence address and therefore, most out-of-state patients may use in-state relative's address in these two states. In addition, as mentioned above, majority of residents in these two states are more urban in nature and most likely to seek medical attention. Lack of treatment facilities, cost of treatment, and cost and mode of transportation, especially for elderly and those with advanced disease may play role in loss of cases in these other states. This health disparity is specifically true for Southern States as the road are less developed, effect of the war on social live, poverty and lack of health education may affect the number of South Sudan's patients seeking help at the capital. In addition, most of the southern patients seek medical assistance in neighboring southern countries such as Uganda and Kenya than traveling to Khartoum.

In Sudan, there are more than 300 tribes, including Danagla, Gulyean, and Shygea in the north; Bija in the east; Kababish, Hamar, Nuba, Baggara, and Fur in the west; Dinka, Newir, and Sheluk in the south. The people come from numerous different ethnic backgrounds, mainly Arab in the north, and African in the south. Cancer cases were more among the Gulyean, Shygea, and Danagla tribes than any other tribes in Sudan. These tribes were specifically examined because of rumors that indicated that Northern States has the highest rate of cancer burden. This increase in cancer was attributed to the abnormal radioactivity due to existence of dumped nuclear waste in north. Although an investigation by Bashier et al., [3] funded by the government, comparing the calculated absorbed dose rate in air and the corresponding annual effective dose with similar data from different regions in Sudan, worldwide, and from well recognized high natural radiation background areas, found that the Northern States falls within the category of normal radiation background in the world.

The overall top ten cancer sites among registered patients were breast, leukemia, esophagus, non-Hodgkin lymphoma (NHL), cervix, ovary, unknown, prostate, bladder, and thyroid cancers. This picture is, to some extent, similar to the pattern of cancer incidence in the developed rather than the developing countries [1]. The number of female patients was slightly more than male and this may be attributed to the number of breast cancer registered, due to awareness bias as a result of breast cancer symptoms [4], in contrast to prostate cancer. The maximum cancer cases number was observed in 45-64 year age group in both male and female patients. There is a possibility of under-registration of clinically diagnosed cases in older patients. Such patients may not be fully investigated and treated symptomatically and sent home; therefore, their record may not be available in in-patients medical record of the investigated institutions.

Breast cancer was the most commonly diagnosed cancer in RICK and NCI-UG centers and account to one fifth of cancer reported in both males and females. This is in agreement with previously reported data from Sudan [2,5,6]. By gender, breast cancer was the most frequently treated cancer in these centers accounting to 30.81% of all cancer in females almost one third of all female cancers [6]. This trend in breast cancer in Sudan was also seen in other African countries. Previously breast cancer was the second leading cause of cancer death among women in 2008 in Sub-Saharan Africa. Recently it was noted to become the most commonly diagnosed cancer in women in several Sub-Saharan African countries, a shift from previous decades in which cervical cancer was the most commonly diagnosed cancer in many of these countries [7]. Many risk factors associated with urbanization and economic development were cited to contribute to this increase in breast

cancer and these include early menarche, late childbearing, having fewer children, obesity, and increased awareness and detection.

Leukemia ranked the second most diagnosed cancer accounting for 11.7% of all cancers in both sexes during the study period. It ranked second in Sudanese men and third in women compared to eighth and tenth in developing countries, respectively [8,9] Twenty years data (1984 to 2004) from RICK showed both leukemia and NHL predominate in men [4]. This cancer picture differs from what is observed in sub-Saharan Africa but somewhat similar to reports in Arab population. Leukemia is one of the 10 most common malignances in Jordan, Egypt, Libya, Saudi Arabia and others. In these countries, it is also the major form of pediatric cancer. About 60-70% of patients with leukemia are older than 50 years. Risk factors include chemical and radiation, smoking, and human T-Cell leukemia virus. However, high rate of consanguinity does not affect the incidence of leukemia in these countries [10].

Esophageal cancer ranked third among most commonly diagnosed cancers in RICK and NCI-UG. Actually, it is the leading cause of death in East Africa when compared to Northern and Middle and Western Africa. In this region, it is more than seven times higher in men and more than 4 times as high among women compared to other 3 regions. Risk factors associated with the disease included nutritional deficiency, alcohol consumption, and corn diet [7].

Cervical Cancer ranked the fifth among most diagnosed cancers, during the study period, in both sexes and is the second most frequently diagnosed cancer in females in both centers. Other sub-Saharan African countries such as Zambia, Malawi, Mozambique, and Tanzania have the highest cervical cancer rates (50 cases per 100,000) worldwide [11]. Reason being either the increase in breast cancer diagnosis in Sudan as mentioned above. The mean age of patients presenting with cervical cancer is 53.25 years [12]. This may be attributed to under reporting as Sudanese women in that age group is usually not open about their gynecological problems with family (husband or sons are the ones financially responsible party for treatment). The most common histopathological type of cervical cancer in Sudan was squamous cell carcinoma and the majority of cases (66.1%) were large cell non-keratinizing [12]. The major risk factor for cervical cancer is papilloma virus, however, few not well-powered studies examined the association of HPV prevalence and cervical cancer in Sudanese women.

Ovarian cancer is the one of the most lethal gynecological malignancies due to late presentation, poor response to therapy and high recurrent rate. The picture of ovarian cancer prevalence seen in this study is similar to that worldwide [13]. It ranked sixth among all cancers diagnosed and fourth among female cancers. It is also ranked sixth in Sub-Saharan Africa, seventh in East Africa, fifth in Northern and Western Africa, twelfth in Southern Africa. In countries surrounding Sudan, ovarian cancer rank third in Egypt and Kenya, fourth in Eritrea and eighth in Ethiopia and Uganda [11]. Although the etiology of ovarian cancer is not well understood, multiparty, lactation, oral contraceptive use, and tubal ligation or hysterectomies are inversely associated with risk [14-15], whereas estrogen-only menopausal therapy, tobacco smoking, and other environmental, occupational, and genetic factors are positively associated with ovarian cancer [16-17].

Prostate cancer in sub-Saharan Africa emerged as the most common cancer and registries records suggest that the disease is increasing in prevalence. It was the eight most common cancers in Sudan compared to fifth in the world. However, by gender it ranked first in Sudanese men. Data from sub-Saharan African countries in 2002 showed that prostate

cancer constituted 6-10% of all cancers in male and that the disease was less common in North African countries accounting for only 4.8% of all cancers in male [18]. However, other African populations showed higher rate of prostate cancer. It is the most commonly diagnosed cancer among men in Southern and Western Africa including South Africa, Nigeria and Cameroon [7]. Low incidence rates were also reported in Red Sea [19] and Western states in Sudan [20]. However, the low prevalence rate may reflect less diagnosis and lack of screening programs than disease occurrence. Risk factors for prostate cancer in Sudan was examined by Hamad and Abuidris [21] in Gezira state and found to include age, education level, occupation, unhealthy habit such as smoking and high fat intake and obesity, similar to other part in Africa [22].

About 6.8% of cancer patients registered in both institutions for the period 2000-2006 were children. Major childhood cancers were the leukemia, followed by NHL, lymphoma, retinoblastoma, brain tumors and Wilms tumors. This pattern was reported previously in El Gezira State, central Sudan [23] and similar pattern have been seen in North African countries such as Tunisia [24] and Morocco [25].

Cancer of the liver, colorectal and lung were not among the top 10 cancers in this study as reported in Globocan 2008 and were included under others. This discrepancy may be due to the data source or method of data collection. Due to the lack of proper cancer registry in Sudan, this present study has many limitations. Uncertainty in recorded ages, tumor sites, biopsied tumors vs. non-biopsied tumors, and cancer amendable to treatment vs. those not may have contributed to underestimation of number of cancers in Sudan.

5. CONCLUSION

The information presented in this study, although is hospital-based, shed the light on the numbers of cancer cases diagnosed and treated in cancer care-providing facilities in Sudan that may aid in drawing attention to the cancer situation in the country. This information confirms the necessity of establishing a population-based cancer registry with rigorous data collection and completion.

CONSENT

Not applicable.

ETHICAL APPROVAL

Not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Parkin DM, Whelan SL, Ferlay J, Teppo L, Thomas BD. Cancer incidence the five Continents VIII. IARC Scientific Publication No. 155, Lyon, France, 2002.
2. Hamad HM. Cancer initiatives in Sudan. Annals of Oncol. 2006;17:32-36.

3. Hamed Bashier E, Salih I, Khatir Sam A. GIS Predictive mapping of terrestrial gamma radiation in Northern State, Sudan. RadiatProtDosimetry. 2012;151(3):500-10.

4. Awadelkarim KD, Mariani-Costantini R, Elwali NE. Cancer in the Sudan: An overview of the current status of knowledge on tumor patterns and risk factors. Sci Total Environ. 2012;423:214-28.

5. Awadelkarim KD, Arizzi C, Elamin EO, Hamad HM, De Blasio P, Mekki SO, Osman I, Biunno I, Elwali NE, Mariani-Costantini R, Barberis MC. Pathological, clinical and prognostic characteristics of breast cancer in Central Sudan versus Northern Italy: implications for breast cancer in Africa. Histopathology. 2008;52(4):445-56.

6. Ahmed HG, Ali AS, Almobarak AO. Frequency of breast cancer among Sudanese patients with breast palpable lumps. Indian J Cancer. 2010;47(1):23-6.

7. Jemal A, Bray F, Forman D, O'Brien M, Ferlay J, Center M, Parkin DM. Cancer Burden in Africa and Opportunities for Prevention. Cancer. 2012;118(18):4372-84.

8. Ferlay J., Parkin DM, Steliarova-Foucher E. Estimates of cancer incidence and mortality in Europe in 2008. Eur J Cancer. 2010;46.4:765-781.

9. Jones LA, Chilton JA, Hajek RA, Iammarino NK, Laufman L. Between and within: international perspectives on cancer and health disparities. J ClinOncol 2006;24(14):2204-08.

10. Tadmouri GO, Nair P. Cancers in Arab populations: concise notes. Hamdan Med. J. 2012;5(1):79-82.

11. Ferlay J, Shin HR, Bray F, Forman D, Mathers C, Parkin DM. Estimates of worldwide burden of cancer in 2008: GLOBOCAN 2008. Int J cancer.2010;127(12):2893-2917.

12. Husain N, Helali T, Domi M, Bedri S. Cerivcal cancer in women diagnosed at the National Health Laboratory, Sudan: A call for screening. Sudan Med J. 2011;6(3):183-190.

13. Jemal A, Bray F, Center MM, Ferlay J, Ward E, Forman D. Global cancer statistics.CA Cancer J Clin. 2011;61(2):69-90.

14. Permuth-Wey J, Sellers TA. Epidemiology of ovarian cancer. Methods Mol Biol. 2009;472:413–437.

15. Sueblinvong T, Carney ME. Current understanding of risk factors for ovarian cancer. Curr Treat Options Oncol. 2009;10:67–81

16. Antoniou AC, Gayther SA, Stratton JF, Ponder BA, Easton DF. Risk models for familial ovarian and breast cancer. Genet Epidemiol. 2000;18:173–190.

17. Grosse Y, Baan R, Straif K, Secretan B, El Ghissassi F, Bouvard V, Benbrahim-Tallaa L, Guha N, Galichet L, Cogliano V. WHO International Agency for Research on Cancer Monograph Working Group. A review of human carcinogens Part A: pharmaceuticals. Lancet Oncol. 2009;10(1):13-4

18. Parkin DM. The global burden of urinary bladder cancer. Scand J UrolNephrol Suppl. 2008;218:12-20.

19. Ageek AK, Ali BM, Awadelkarim MA. Pattern and incidence of cancer in Red Sea State, Sudan. Sudan J Med Sci. 2007;2:115-9.

20. Doumi EBA, Ahmed MA, Hamad ASM. Pattern and incidence of cancer at El Obeid Hospital, Western Sudan. Sudan J Med Sci. 2009;4(1):43-47.

21. Hamad FA, Abuidris DO. Risk factors for prostate cancer patterns among Gezira State-Central of Sudan. IIUM Eng J. 2011;12(4):203-2011.

22. Okobia MN. Cancer care in sub-Saharan Africa, urgent need for population-based cancer registries. Ethiop J Health Develop.2003;17(2):89-99.

23. Abuidris OA, Ahmed ME, Algaili EM, Arora R. Childhood cancer un Sudan:1999-2007. Trop Doct. 2008;38:208-210.

24. Missaoui N, Khouzemi M, Landolsi H, Jaidene L, Abdelkrim SB, Abdelkader AB, Beizig N, Yaacoubi MT, Hmissa S. Childhood cancer frequency in the center of Tunisia. Asian Pac J Cancer Prev. 2011;12(2):537-42.
25. Msefer Alaoui F. Rabat Hospital for Children,1983–85.In: Parkin DM, Stiller CA, Draper GJ, Bieber CA, Terracini B, Young JL, eds. International Incidence of Childhood Cancer (IARC Scientific Publications No.87). Lyon: IARC, 1988:33–5.