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Cancer Burden in the Red Sea State, Sudan: A Ten Years of Incidence, Distribution, and Trends: (2016-June2025)

Dr. Awad Abdalla Widaa
Faculty of Medicine | Red Sea University | Sudan

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* Corresponding author: awadwidaa137@gmail.com

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Abstract: Cancer is an increasing health concern in the Red Sea State while population-based data remain scarce. Aim: To describe adult cancer incidence, geographic distribution and trends in the Red Sea State between 2016 and 30 June 2025 and to assess the impact of the April 2023 armed conflict and patient displacement on registry measures. Patients and Methods: A descriptive retrospective review of all histopathologically confirmed adult cancer cases registered at Port Sudan Oncology Centre (POC) from 2016 to 30 June 2025 (n=3,265). Demographic and clinical data were abstracted from paper and electronic records; analyses used SPSS v20 to compute frequencies, age- and sex-specific and age-standardized rates; chi-square test evaluated associations ($p<0.05$). Results: A total of 3,265 cases were recorded (annual caseload ≈300–350; overall incidence 36.5/100,000). Females predominated (F:M = 1.74:1). Top five primary sites were breast (26.0%), leukaemia (12.4%), head & neck (7.7%), prostate (7.5%) and oesophagus (6.5%). The largest proportion was aged 59–78 (43.9%); 84.6% resided in Port Sudan. The 2023 conflict and subsequent displacement increased referrals to POC (≈21.4% of new patients in early 2024 were displaced). Conclusion: This is the largest contemporary survey of cancer burden in the Red Sea State. Findings highlight the urgent need to strengthen regional cancer registration, expand targeted prevention and screening, improve access to diagnostics and treatment, and plan resources to mitigate the impact of conflict on cancer care.
Keywords: Cancer incidence; prevalence; epidemiology; tumors; Red Sea State; Port Sudan Oncology Centre; displacement; armed conflict.

عبء السرطان في ولاية البحر الأحمر، السودان: عشر سنوات من الإصابات والتوزيع والاتجاهات (2016–30 يونيو 2025)

الدكتور/ عوض عبد الله وداعه
كلية الطب | جامعة البحر الأحمر | السودان

المستخلص: مقدمة: يشكل السرطان عبئًا صحيًا متزايدًا في ولاية البحر الأحمر مع ندرة بيانات السجل السكاني. الهدف: وصف معدلات الإصابة بتسرطن البالغين، وتوزيعها الجغرافي، واتجاهاتها في ولاية البحر الأحمر خلال الفترة 2016 حتى 30 يونيو 2025، وتقييم أثر الصراع المسلح (أبريل 2023) ونزوح المرضى على تسجيل الحالات. المرضى والمنهجية: دراسة وصفية استعادية شملت جميع الحالات الباثولوجية المؤكدة لدى البالغين المسجلين في مركز بورتسودان للأورام (POC) بين 2016 و2025/6/30 (n=3,265). استُخرجت البيانات الديموغرافية والسريرية من السجلات الورقية والإلكترونية وحُللت باستخدام SPSS v20 لحساب التوزيعات، المعدلات النوعية والعمرية، ومعدلات معيارية للعمر؛ أُجري اختبار كاي-تربيع للعلاقات ($p<0.05$). النتائج: سجّل المركز 3,265 حالة (حمل سنوي ≈300–350؛ معدل حدوث إجمالي 36.5/100,000). كانت الإناث أكثر تأثرًا (نسبة أنثى:ذكر = 1.74:1). أكثر خمسة مواقع أولية شيوعًا: الثدي (26.0%)، اللوكيميا (12.4%)، أورام الرأس والرقبة (7.7%)، البروستات (7.5%) والمريء (6.5%). كانت الفئة العمرية 59–78 الأكثر تمثيلاً (43.9%)، و84.6% من المرضى مقيمين في بورتسودان. أثر الصراع أدى إلى زيادة تدفق المرضى إلى المركز؛ حوالي 21.4% من الحالات الجديدة في بداية 2024 كانت لمرضى نازحين. الخلاصة: هذه أكبر دراسة معاصرة لعبء السرطان في الولاية؛ النتائج تستلزم تعزيز نظم التسجيل الإقليمي، وبرامج الوقاية والفرز، وتحسين الوصول للتشخيص والعلاج، وتخطيط موارد يراعي آثار النزوح والنزاع على رعاية السرطان.
الكلمات المفتاحية: السرطان، معدلات الإصابة، الانتشار، الوبائيات، ولاية البحر الأحمر، مركز بورتسودان للأورام، النزوح.

Introduction:

Background: Cancer is one of the leading causes of death worldwide. In 2022. Agency for Research on Cancer (IARC,S) projects that there were an estimated 20 million new cancer cases and 9.7 million deaths, it is projected to grow in the years to come and is expected to reach 21.4 million new cases and 13.2 million deaths by 2030. And by 2050, the number of cancer cases could reach 35 million. [1] According to a projection of the World Health Organization (WHO) highlights that cancer is considered as the second cause of death in developing countries (10.4%), where as it is the first cause of death in developed countries (26.6%).[1,2] The World Health Organization (WHO) reports estimates that around one third of cancers are caused by several leading environmental and behavioral risk factors, specifically tobacco being the biggest culprit among all causative factors. [3] IARC,S also shows that 10 types of cancer collectively comprised around two-third of new cases and death globally in 2022. Lung cancer was the most commonly occurring cancer worldwide, with 2.5 million new cases. accounting for 12.4% of the total new cases. Female breast cancer ranked second (2.3million cases 11.6%), followed by colorectal cancer (1.9 million cases, 9.6%), prostate cancer (1.5 million cases ,7.3%) and stomach cancer (970000cases,4.9%) of the total new cases. Lung cancer was the leading cause of cancer death (18.7% of total cancer death), followed by colorectal cancer (9.3%), liver cancer (7.8%), breast cancer (6.9%) and stomach cancer (6.8%) of total cancer death. For women, the most common leading cause of cancer death was breast cancer, where as it was lung cancer for men. Globally, for men, prostate and colorectal cancers were the second and third most commonly occurring cancer, while lung and colorectal cancer were the second and third most common cancer for women. [4,5] In Africa, in 2022, Africa experienced an estimated 1.1 million new cancer cases and 711,429 cancer –related death. It is expected to increase significantly by 2040, with an estimated 2.1 million new cases and 1,4 million deaths. Despite lower overall incidence, Africa cancer mortality rate is relatively high compared to other regions, suggesting issues with diagnosis and treatment. Breast cancer was the leading malignancy in female in Africa, cervical cancer was ranked second in Africa, while Prostate cancer is the leading cancer in men in many sub-Saharan African countries. [5,6] Cancer continues to receive low public health priority. Thus, cancer poses tremendous burden for the health system, as well as the entire economy, throughout Africa because of both treatment costs and drop-out of working power of patients. [6]

Cancer in Sudan: Sudan's cancer burden is not well-documented because the attention of the health system mainly focuses on communicable diseases such as malaria, tuberculosis and human immunodeficiency virus (HIV)/AIDS. A survey of Sudanese hospitals conducted in 2023 revealed that cancer was the third leading cause of death after malaria and viral pneumonia, Cancers responsible for 16.3% off all non-communicable disease-related death in Sudan, approximately 17000, deaths, accounting for 5% of all deaths annually. [2,7] Although clinical pathways for high-priority cancers have been developed in collaboration with local oncology experts and with WHO technical supports, until the past decade there was no national cancer strategy to provide a strategic direction for national cancer agenda. [2] Breast cancer is the most common cancer, followed by leukaemia, colorectal cancer, prostate cancer, and non-Hodgkin lymphoma. Cancer incidence is increasing among adults, while remaining more or less stable in children. Several factors contribute to the cancer burden in Sudan, including a history of conflict and displacement, limited access to health care, late-stage diagnosis and lack of resources for cancer treatment and prevention. [8]

Cancer Registry in Sudan: However, population-based data on cancer incidence, prevalence, and mortality in Sudan were not available, and most published cancer cases were based on estimates from hospital-based information sources. Most of these sources are maintained by individual health institutions and are mostly paper -based.[9] The first National Cancer Registry (NCR) in Sudan started in 1967; unfortunately, it is no longer acting now due to lack of financial and technical support. The lack of proper cancer registration systems was reflected in the type of published data, as it was mainly hospital-based studies.[10] The first report about cancer in Sudan, "Malignant epithelial tumors in the Sudanese," was published by Hickey in 1959 following a lecture presented to the Royal College of Surgeons, England on 13 March 1958. [11] The report presented data on 1335 malignant epithelial neoplasms histopathologically diagnosed at the Stack Medical Research Laboratories (NHL) from 1935–1954. At that time, the most common tumor sites were the skin (32.8%) followed by the breast (22.9%). Basic as well as clinical research is limited in Sudan and many reasons could be cited, but mainly a lack of financial and technical support .Because of this, very few studies so far have attempted to determine cancer etiology in Sudan. [12,13] The main sources of cancer data are the Radiation and Isotope Center in Khartoum (RICK), handling 80% of cancer cases ,and serving as Sudan's primary data source since the 1960. and the National Cancer Institute of the University of Gezira in Wad Medani, Capital of the Gazira State; Founded in 2008, it supports regional data collection in central Sudan. [9,11] In 2009 ,Sudan established the first National Cancer Registry(NCR)to develop a system that will facilitate creation and maintenance of local and regional data and

assemble these data into a single centrally accessible system. [14] Last update of cancer incidence in Sudan in 2022 with Age-standardized incidence rate for male at 80.6 and for female at 109.7. The top 5 most frequent cancers were breast cancer accounting for 23.2% of the total new cases. colorectal cancer 6%, NHL for 5.3%, Prostate cancer for 4.9% and leukemia for 4.5%. [15] Breast cancer was the leading cause of cancer death (17.5% of total cancer death in Sudan), followed by liver cancer (6.5%) ,colorectal cancer (5.9%), NHL (5.4%) and leukemia (5.3%) of total cancer death. For women ,the most common leading cause of cancer death was breast cancer 20.7%, where as for men ,it was prostate cancer for men at 8.7%. [15] Recently, the Federal Ministry of Health created many new cancer institute in different states of the country for cancer treatment, within which a regional cancer registry would be establish**.**

Cancer in the Red Sea State : Cancer in the Red Sea State is not specifically detailed in the provided search results, nor specifically mentioned in the context of cancer treatment facilities. Early detection of cancer significantly improves treatment outcomes, but unfortunately, in the Red Sea State, the major challenge is the equity and priorizations ,most cancer cases go unreported, and many are diagnosed at advanced stages when the disease has become aggressive or metastasized .This neglect is affecting the three primary tiers of cancer care: prevention, diagnosis, and treatment/management.

Funding for cancer care and research: The usual predisposition for funding is to expect the government to provide all the funds. This is unrealistic in present day in Sudan considering the economic instability and overwhelming challenges that already plague this country. There is need for urgent interventions everywhere ,as everyone is at risk of cancer, we-individuals stakeholders, institutions, and governmental and nongovernmental organizations need to join efforts together to achieve equitable access to cancer care and research funds.

Impact of Armed Conflict on Cancer Care in Sudan: The ongoing war in Sudan on April 2023 has created a cancer crisis ,severely disrupting cancer treatment and care . Armed conflict has disrupted chemotherapy ,hormonal therapy, and targeted therapy for a large percentage of cancer patients (98%). [16] Diagnostic processes , surgery, radiotherapy and palliative therapy have been suspended or delayed, and the collapse of the healthcare infrastructure, particularly in major cancer centers in Khartoum and Wad Medani, has further exacerbated the situation. Patients with cancer have been displaced multiple times in Sudan with grave consequences on the continuity of care. Displacement ,transport barrier ,and financial burden contribute to treatment interruptions lead to migration of a large number of cancer patients to a relatively safe center like Port Sudan Oncology Centre (POC) for treatment. [17,18] The oncology workforce have themselves been displaced yet are working hard to provide services and care for patients under impossible circumstances, bearing in mind that the war has caused significant psychological distress for cancer patients and their families, including fears, uncertainty, and anxiety about the future (Wars inside War). The crisis has also had ripple effects on neighboring countries , particularly regarding the influx of refugees and the strain on health care systems in those countries.[19]

The center provides cancer treatment services for adults. As a result of war, and the influx of cancer patients of all ages to the state, the center has begun offering pediatric cancer treatment services for more than 40 child with cancer.

Patient and Methods:

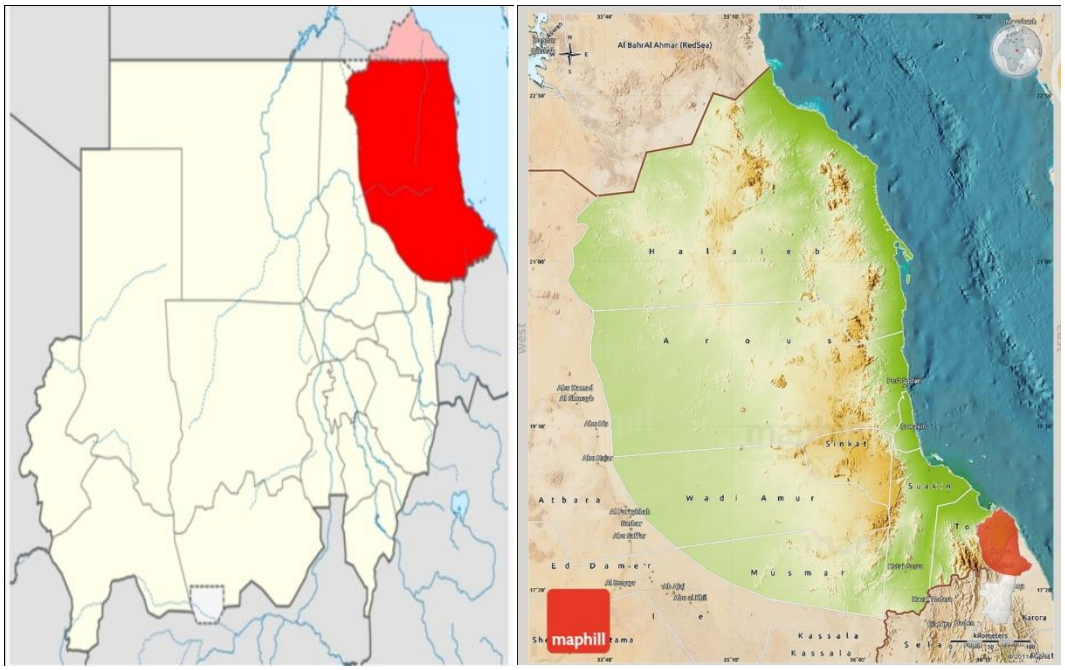
Objective: Cancer incidence in the Red Sea State is increasing, yet their geographic distribution and determinants are incompletely characterized. The present study aims to established the spatial epidemiology of cancer burden in the Red Sea State between 2016 and June 30, 2025 , and delineate the association between cancer burden and the state –level socioeconomic status. Also, this study has reviewed and address the impact of war conflict setting of Sudan in April 2023 and the displacement of patients with cancer , where access to healthcare and resources of cancer management is disrupted . This review is the first papers that focuses up to date on adult cancer, its distribution, and cancer trends in the Red Sea State(RSS) in Northeastern Sudan. The reviews are meant to provide a better understanding and knowledge required to plan appropriate cancer control and prevention strategies in this state and whole country. The study gave a fair representation of cancer profile of Red Sea State, emphasizing population-based registries rather than hospital-based registries .

Population-based Study: This study combined multiple sources for completeness and tried to create a structured response covering the main disadvantage of hospital-based registries, like selection bias, non- representative population coverage, and data incompleteness, limited variables for analysis. and operational challenges affecting data quality challenge with proper citations throughout. This study, help in identification of risk factors disparities with long term trend analysis and supports the development of regional cancer registry.

Setting :Port Sudan Oncology Centre (POC): This center was established in 2015 to cover approximately all adult patients with cancer in the state, to provide cancer management for all adult patients (Chemotherapy, Hormonal therapy, Immunotherapy ,and supportive medications) ,and provides programs for cancer screening and awareness to improve targeted interventions, including improvement of healthcare access, early detection, and multidisciplinary approach management .In the hope, that this centre will provide data on the burden of cancer in Red Sea State, therefore, it considered representative of the cancer situation in the Red Sea State to develop a system that will facilitate the creation and maintenance of local and regional data and assemble these data into a single centrally accessible system, allowing policy makers to implement cancer control measures and prevention strategies.

Study Design: This is a descriptive, retrospective study in which all adult patients presented to Port Sudan Oncology Centre(POC) between 2016 and June 30, 2025 and proved by histopathology were included. Paper medical charts were reviewed .15 patients had incomplete data and were excluded; Epidemiological data were categorized by age, gender, resident state, marital status etc. And information on demographic ,presenting symptoms, pathology, clinical staging, treatment, and follow up was abstracted. Cancer diagnoses were made by standard clinical, pathological and radiological methods. and subjected to statistical analyses by SPSS. Version 20.0.

Population Data: Red Sea State is one of 18 states of Sudan, it lies in the northeast of Sudan, bordering the Red Sea, and shares international borders with Egypt and Eritrea. It is state capital is Port Sudan, which hosts Sudan's main seaport. and has an area of 212,800 km^2 and an estimated urban/rural population of approximately 1.6 million. The sex ratio is slightly higher for females than males, with a ratio of approximately 98.34 males per 100 females (female population= 813,280 and male population= 786,720).(Sudan Humanitarian Update (April-May 2025). Sudan demographics 2024-Statistics Times.com . The original inhabitants of the state are Beja people, tribes who constitute above 60% of current population.



Sudan -Red Sea State Map

Data Management and Statistical Analysis:

Descriptive statistics include (means, frequencies and percentage) were used to summarize the demographic data .we use the chi-square test to examine the relation of cancer with specific age period and geographical distribution, crude as well as gender- and age-specific, incidence rates for each cancer site were derived. Age was categorized into five groups as previously described for age-specific rates. The direct method was used to compute age-standardized rates (ASR) using different standard populations, including (Sudan demographics 2024- Statistics Times.com). Data were verified and analyzed using IBM SPSS statistics for windows, Version 20.0. All statistical tests were considered significant when P Value <0.05.

Results:

A total of 3265 patients with cancer were registered in this study between 2016 and up to June30, 2025. All the patients were Sudanese, i.e. they were all exposed to more or less similar environmental ,dietary and genetic factors. The prevalence rate per year was 300-350 cancer cases. (The overall cancer incidence rate is 36.5 per 100,000). Cancer prevalence increased steeply with age, reaching values of 43.9% in the age group (59-78) but starting to drop after that. Females were more diagnosed with cancer than males , with ratio (1.74**:** 1). All tumor types and locations were diagnosed by standard pathological and clinical procedures. Histological subtypes of tumors were summarized to the corresponding main tumor type. For example, Hodgkin and Non-Hodgkin lymphoma were listed as"lymphoma", acute/chronic myeloic/lymphoblastic leukaemia as"leukaemia". Epithelial tumors at different locations in the head region as "head and neck tumors", and so on.

Geographical Regions Distribution of Cancer in POC:

Cancer's geographical distribution varies in this study, with some cities in the Red Sea State showing a higher incidence rate than others. Port Sudan ,Swakin, and Toker have been identified as having a high incidence of cancer. **Table (1)** As the state capital, Port Sudan has the largest population and therefore records the highest incidence rate of cancer in the state. Furthermore ,some patients register with an address in the state capital instead of their actual place of residence.

Table (1) Geographical Distribution of 3265 patients in POC (2016 to June30,2025).

Residence	Frequency	Percent
Port Sudan	2762	84.6 %
Swakin	196	6 %
Tokar	194	5.9 %
Sinkat	49	1.5 %
Jabate	29	.9 %
Haya	16	.5 %
Missing value	19	.6 %
Total	3265	100.0 %

Top 10 Most Common Primary Cancer sites in PCO: The Top ten most common primary cancer sites in both sexes in the Red Sea State were breast cancer (26%), leukemia (12.4%), head and neck cancers(7.7%), prostatic carcinoma(7.5%), esophageal cancer(6.5%), Non Hodgkin lymphoma(5.5%), Colorectal cancer(5.3%), Endometrial Carcinoma (3.8%), Ovarian Cancer(3.4%), and liver cancer (3.3%),accounting for (81.4%) of all malignancies. **Table(3) Figure (1)**

Table (2) Cancer prevalence by gender in POC (2016 to June30,2025).

Year	Patient	Number	RFR (%)	Total
2016	Male	53	1.6 %	186
	Female	133	4.2 %	5.8%
2017	Male	114	3.5 %	299
	Female	185	5.8 %	9.3%
2018	Male	95	3 %	289
	Female	194	5.9 %	8.9%
2019	Male	78	2.4 %	254
	Female	176	5.4 %	7.8%
2020	Male	34	1 %	142
	Female	108	3.3 %	4.3%
2021	Male	28	.9 %	153
	Female	125	3.8 %	4.7%

Year	Patient	Number	RFR (%)	Total
2022	Male Female	37 69	1.2 % 2 %	106 3.2%
2023	Male Female	150 262	4.7% 8%	412 12.7%
2024	Male Female	362 729	11.1% 22%	1091 33.1%
Up to June 30,2025	Male Female	112 221	3.4% 6.8%	333 10.2%
Total		3265	100 %	100%

Table(3) Prevalence of Most common primary cancer sites in POC (2016 to June30,2025)

No	Cancer Type	Male	Female	Total
1	Breast Cancer	18 (.6%)	829 (25.4%)	84 (26 %)
2	Leukaemia	192 (5.9%)	232 (7.1%)	424 (13%)
3	Head and Neck cancer	160 (4.9%)	90 (2.8%)	250 (7.7%)
4	Prostatic Carcinoma	246 (7.5%)	0 (0%)	246 (7.5%)
5	Oesophageal Cancer	69 (2.1%)	135 (4.2%)	204 (6.3%)
6	Non-Hodgkin lymphoma	122 (3.7%)	59 (1.8%)	181 (5.5%)
7	Colorectal cancer	95 (2.9%)	78 (2.4%)	173 (5.3%)
8	Endometrial Carcinoma	0 (0%)	124 (3.8%)	124 (3.8%)
9	Ovarian Cancer	0 (0%)	111 (3.4%)	111 (3.4%)
10	Liver Cancer	31 (1%)	76 (2.3%)	107 (3.3%)
11	Cervical Cancer	0 (0%)	102 (3.1%)	102 (3.1%)
12	Pancreatic Cancer	35 (1.1%)	36 (1.1%)	71 (2.2%)
13	Gastric cancer	39 (1.2%)	28 (.9%)	67 (2.1%)
15	Ca unknown primary	26 (.8%)	24 (.7%)	50 (1.5%)
16	Thyroid cancer	16 (.5%)	30 (.9%)	46 (1.4%)
17	Vaginal cancer	0 (0%)	44 (1.3%)	44 (1.3%)
18	Skin cancer	22 (.7%)	11 (.3%)	33 (1%)
19	Lung cancer	27 (.8%)	6 (.2%)	33 (1%)
20	Bone cancer	19 (.6%)	11 (.3%)	30 (.9%)
21	Soft tissue sarcoma	16 (.6%)	12 (.6%)	28 (.9%)
22	Urinary bladder cancer	13 (.4%)	6 (.2%)	19 (.6%)
23	Gall bladder cancer	5 (.2%)	11 (.3%)	16 (.5%)
24	Small bowel cancer	8 (.2%)	5 (.2%)	13 (.4%)
25	Brain cancer	6 (.2%)	5 (.2%)	11 (.4%)
26	Testicular cancer	8 (.3%)	0 (0%)	8 (.3%)

No	Cancer Type	Male	Female	Total
27	Multiple myeloma	4 (.1%)	3 (.1%)	7 (.2%)
28	Anal cancer	3 (.1%)	2 (.1%)	5 (.2%)
29	Adrenal gland cancer	3 (.1%)	1 (.03%)	4 (.13%)
30	Molar pregnancy	0 (0%)	3 (.1%)	3 (.1%)

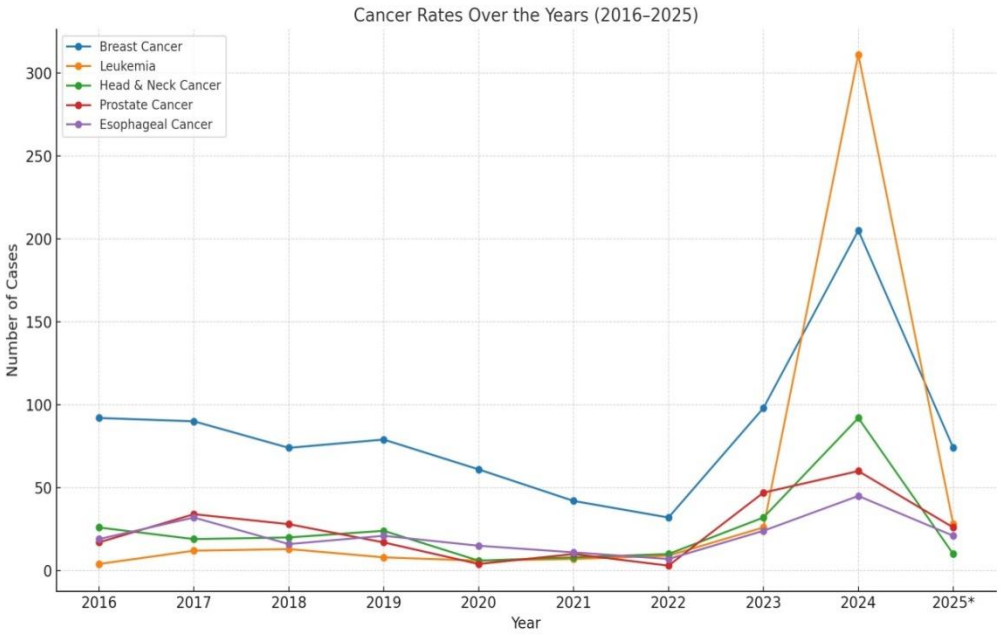


Figure (1) Pattern of annual incidence for top five most common cancer in POC (2016 to June30,2025).

Gender-and Age-specific Cancer Incidence Rates:

The women to men ratio was 1.74**:** 1 .When the tumor distribution was specified according to gender, **Table (2)** the gender-related tumors types were top ranked, i.e. prostatic carcinoma as most frequent male cancer (20.7%) followed by leukaemia (16%), head and neck tumors(13.4%), non-Hodgkin lymphoma (10.2%), colorectal cancer (8%), and esophageal carcinoma(6.4%), that representing approximately (74.7) % of all male cancers. **Figure (2) Table(3)** While in female, breast carcinomas are the leading female tumors (40%), followed by leukaemia (11.2%), esophageal cancer (6.5%), endometrial carcinoma(6%), ovarian cancer (5.4%), and cervical carcinoma(4.9%), accounting for (74%) of all female cancers. **Figure (3) Table(3)** , the most common age group was (59—78) years they were 43.9%, with a mean age at diagnosis of 49.5 years . Focusing on the age of patients with cancer at diagnosis revealed interesting gender-related differences. The most common age group in men at diagnosis was (59 —78) years, accounting for 47.9%, while the most common age group in women at diagnosis was (39-58) years, accounting for 43.9%. This may, at least in part, be due to the later onset of prostatic carcinoma (median age=59-75 years) compared to breast cancer (median age=35-48years) **Table(4)** . Remarkably, the cancer incidence differed considerably between the cities of the state ,most of patients lives in the capital of the state (84.6 %) , this may be due to higher levels of exposure to carcinogenic chemicals .and, with increased urbanization, industrialization, accompanied by changes in lifestyle ,cigarette smoking ,and environmental pollution might play a role. More detailed analyses are required to identify the corresponding risk factors. Also, there was a significant correlation between the number of cancer cases, marital status and the occupation of patients. Cancer was significantly more frequently diagnosed among those who were married, where as housewives (42.3 %) of all patients and (64.6%) of all females participants in this study. In last two years due to impact of Armed Conflict in Sudan on April 2023, over 40000 patients with cancer have been displaced to peripheral oncology centers for treatment, increasing the flow of those patients to the Port Sudan Oncology Centre(POC) for treatment .Since the beginning of 2024 about 305 displaced patients with cancer (21.4% of all new patient number during this period) received treatment of cancer on Port Sudan Oncology Centre (POC) .

Table (4) Age-adjusted cancer prevalence in POC from (2016 to June2025).

Age	Frequency	Percent
Less than 18	41	1.3 %
18 – 38	405	12.4 %
39 – 58	1092	33.5 %
59 – 78	1539	47 %
79 +	188	5.8 %
Total	3265	100 %

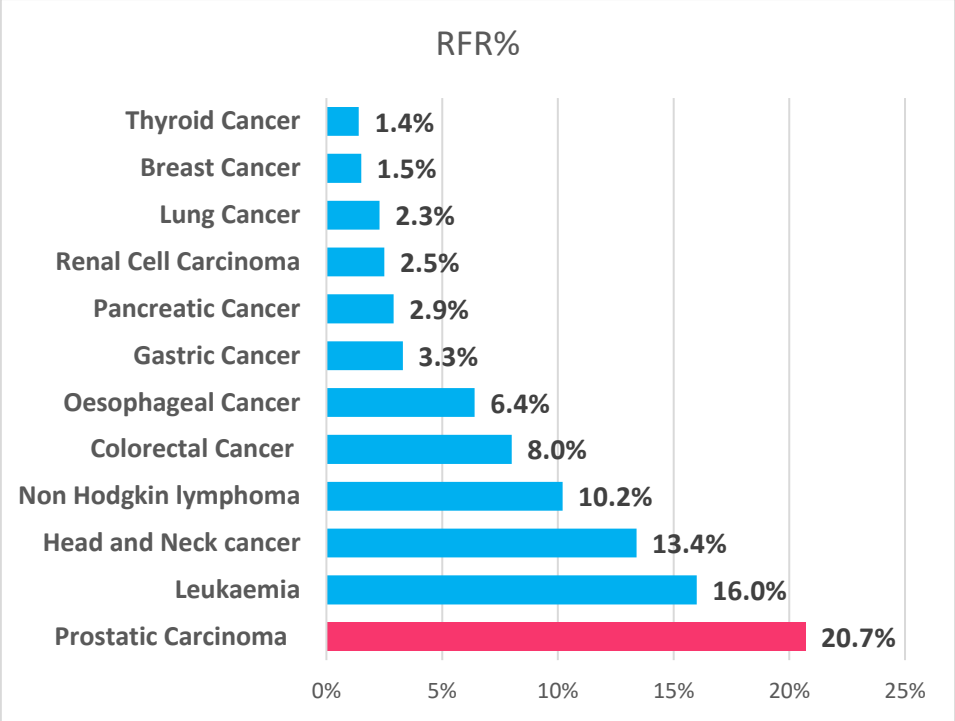


Figure (2) Incidence of different tumor types among male gender in POC from (2016 to June 30,2025).

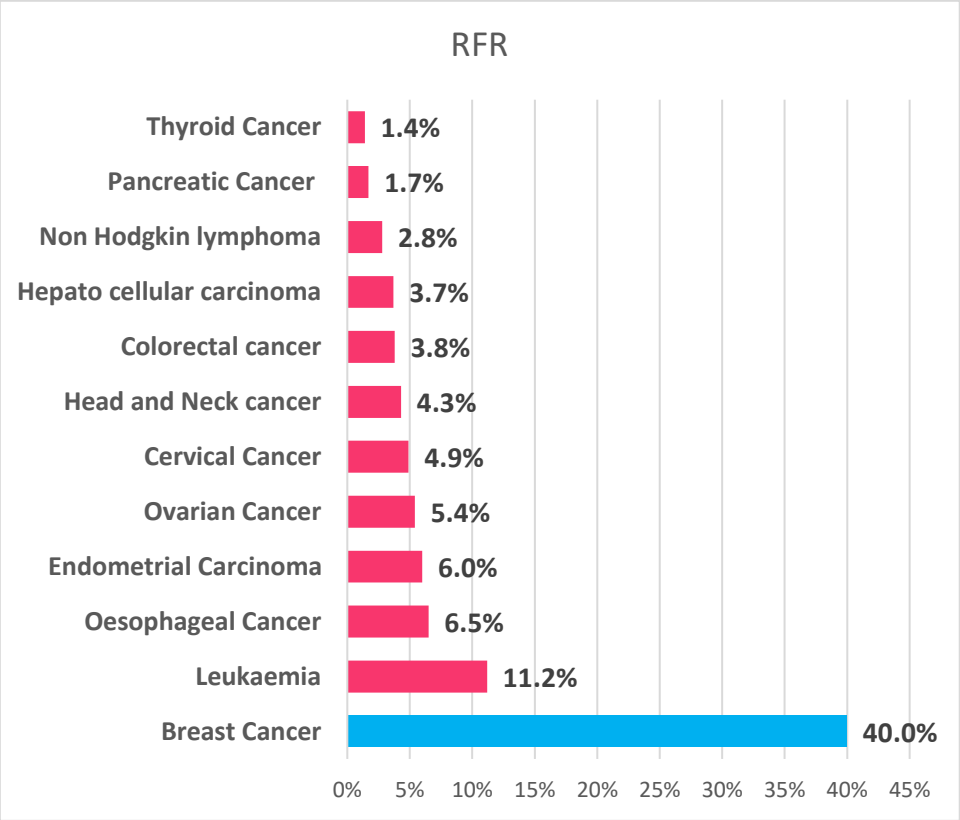


Figure (3) Incidence of different tumor types among female gender in POC from (2016 to June 30,2025).

Ethnic and Racial -specific Cancer Incidence Rates:

Nearly (49.8%) of patients were descendants of bane amer tribes, (19 %) Hdandawa tribes, (1.8%) Rashaida tribes,(22.3%) from Northern Sudan, (6.2%) were western and (1%) were others.

Discussion:

This study focused on the cancer cases diagnosed and treated at the Port Sudan Oncology Centre (POC) in Red Sea State during the period 2016 to June 30,2025. Based on the results of one registry in a single state (Red Sea State) and may have an impact on understanding the current situation of cancer at the national level. The estimated urban/rural population is approximately 1.6 million (female population= 813,280 and male population= 786,720). We reported on 3,265 cancer cases recorded at Port Sudan Oncology Centre (POC) during the study period. This is the first and the largest study yet on the burden of cancer in the Red Sea State. During the study period. Striking changes from one year to the next may occur in some cancers during the study time . While the incidence of cancers associated with poverty and infection (liver, cervix, esophagus,lymphoma) shows little decline, and residual burden of the AIDS-associated cancer remains a major burden.

The overall numbers of cancers diagnosed in the Red Sea State increased from around 260 cases between 2003-2006 [20] to more than 3,265 cases between 2016 and June 2025. During the study period, more women had cancer than men ,with a women to men ratio of 1.74**:** 1. However, this ratio resemble the national records in Sudan [7] but is very modest compared to what was reported by Jedy-Agba et al. for Nigerians as the number of women was twice the number of men. [21] The increase in the number of women cancer incidence may be attributed to the number of breast cancer cases registered and under diagnosis of prostate cancer. Despite more females than males being diagnosed with cancer during study period, the risk of cancer has always been higher in males than in females. The contrasting patterns between the numbers and rates between the sexes are partly due to there being more females living longer than males, although the population of both sexes continues to increase. To understand the implications of these trends over time, each cancer needs to be considered separately. The most frequent types of cancer in both sexes were breast cancer , leukaemia , head and neck cancers, prostatic carcinoma, and esophageal cancer, which account for 60.1% of all malignancies in this study. The prevalence of these

tumor types in these records is partially different from those in developed countries. While breast and prostatic carcinoma belong to the top leading cancer types worldwide [4,5] , leukaemia and esophageal cancer occurred much more frequently in this study than in the U.S.A and Europe [4,5,22,23]. This is also different from the old local records done in 2006 [20] ,but similar to National records in Sudan [14,24] and African records. [6,25]

Lung Cancer: Lung cancer is the second leading cause of morbidity and the top leading cause of mortality in the U.S.A. ,[4,21,26] it ranks only the 20th most frequent tumor in Sudanese patients [14,24] and the nineteenth most frequent tumor at Port Sudan Oncology Centre (POC) records. The reason for the low frequency of lung carcinoma in this study may be that cigarette smoking is not that common in Sudan compared to the U.S.A. and other developed countries. This result also in accordance with the low frequency of lung cancer in the Arab world. [27,28]

Breast Cancer: Although some risk factors for breast cancer may be similar in Sudan (Red Sea State) and other developing countries .e.g. Obesity, early menarche, decreased detection awareness, late and few births, which may be attributed to an increase in the urbanization rate and economic development in developing countries. Breast cancer dominates the pattern of cancer prevalence for females because it is the most commonly diagnosed tumor at Port Sudan Oncology Centre (POC).Having replaced lung cancer as the most commonly diagnosed cancer globally. Nearly 40% of all female patients with cancer in this study have been diagnosed with breast cancer. 88.4% are married. It is important to highlight that patients were most often Bani Aamir(38.4%); 37% were Northern Sudan and 14.3% were Hdandawa. The ASRs of breast cancer in women living in the Red Sea State were 66.8 per 100,000, which were observed to be higher than what was reported in black women in Harare, Zimbabwe (54.3 per 100,000, 2018) and ranked the second most frequent caner after cervical cancer among women there, [29] and in Kampala ,Uganda (31.0 per 100,000 in 2021) in East Africa. [30] The incidence rate of breast cancer in women in Red Sea State was also higher compared to North Africa, such as in Libya with an ASR of (42.9 per 100,000 in 2003-2018), [31] (39.12 per 100,000) in Tunis, Tunisia (2002–2030), [32] and (48.8 per 100,000) in Egypt in 2023. [32-34] Statistical analysis using the chi-square test, revealed a higher incidence of 60% of malignancies among women aged 39-58 years . The median age is 35-48years. We recorded more than 13% of the patients are under the age of 35 years in this study. Only (4,2%) of female developed breast cancer after age of 75 years, this is similar to what has been reported from previous studies in Sudan. [35,36] Unfortunately, breast cancer occurs at a young age and is frequently in a more advanced stage at diagnosis than in western countries where the median age at the time of diagnosis is 62 years, with 66% diagnosed at a localized stage. [4,26] and the longer a woman lives without cancer, the lower her risk of developing breast cancer. The most common stages of breast cancer at the time of diagnosis were locally advanced or metastatic stage (53% for stage 3, followed by 21% for stage 2), with no recorded cases at stage 1. The proportion of patients with an unknown stage was 26% .The late diagnosis of breast cancer in this state is largely due to many factors**:** (1) Younger population demographics compared to many Western countries. (2)Unfavorable attitudes towards cancer screening. (3) Many women in this state seek medical attention after noticing symptoms , (4) loss of awareness of breast cancer symptoms among the community, and hence late referral of suspected breast cancers to diagnostic services or believes of seeking traditional healer. This un healthy practice contribute significantly to late diagnosis of cancer; (5)Having false negative biopsies results, (6)Socioeconomic constraints factors ,(7) Genetic predisposition.

The impact of the early onset of breast cancer in the Red Sea State is that the breast cancer exhibits more aggressive behavior with a high mortality rate.

Prostate Cancer: By 2004 prostatic carcinoma had become the most common cancer among men, with incidence varying significantly across the globe. The risk of prostate cancer increases with age. Prostate cancer in this study ranked as the fourth most frequent among all cancer sites in the Red Sea State . However, by gender, it ranked the first among the male study population and represented 20.7 % of all male cancers at Port Sudan Oncology Centre (POC). While prostate cancer was less frequent in the past, its incidence has recently increased, possibly due to improved diagnostic technique. It is equally distributed among different ethnic groups of this study. Although prostate cancer, which is the most common site overall, has by far the highest rate in the age group over 59 (median age=59-75 years) ,with ASRs being 22.4 per 100,000. This figure was similar to the national records in Sudan, [14,37] and similar to incidence rates reported in the Western states of Sudan, [38] but were relatively lower compared to other African countries. The data from Harare, Zimbabwe (1991–2010); Kampala,Uganda (1991–2006); Ibidjan, Ivory Coast Ibadan (1995–1997); and Abuja. Nigeria reported much higher ASRs for prostate cancer. [6,39] Most African populations reported higher rates of prostate cancer and more advanced disease presentation compared to the Sudan report. [6,34] The low incidence rate in this study may reflect fewer diagnosis

and lack of screening programs than disease occurrence. The common potential risk factors for prostate cancer among patients referred to Port Sudan Oncology Centre (POC) included age, and history of tobacco and alcohol consumption. Risk factors for prostate cancer in Sudan were examined by Hamad and Abuidris in Gezira state and found to include age, education level, occupation, unhealthy habit such as smoking. high fat intake and obesity and were found to be similar to other parts of Africa. [37]

Colorectal Cancer: Colorectal Cancer is the seventh most common cancer tumor in both sexes of this study, and represented 5.3% of all cancer recorded in this study . Males and females are equally affected. And this figure was observed to be less frequent than what was reported in national records in Sudan ,where colorectal cancer is the fourth most common type of cancer [14,36],and lower when compared with African records, where it ranked as the third most common cancer. [40,41] Also, these figures are different from those in developed countries, where colorectal cancer is the third most commonly occurring cancer worldwide (1.9 million cases, 9.6%), after lung cancer and breast cancer. [4,5] Colorectal cancer is a significant health concern; it has received less attention compared to other cancers like breast cancer in Sudan. high frequency were in the age group above 59 years (55%) ,and then the age group less than 38 years (27.5%) of the patients , and a one recorded case at seventeen years of age . The implementation of screening program remains a challenge. A notable feature of colorectal cancer in the Red Sea State is the tendency for the disease to affect a younger population than what is typically reported internationally . [4,41,42] the Risk of colorectal carcinoma may be obesity and a fat-rich diet . Interestingly, human papilloma virus (HPV) infection may also be involved in the development of breast and colorectal carcinoma . [40] Lower incidence rate, presentation in advanced stage and aggressive pattern are the famous features of colorectal cancer in Red Sea State. The younger age at presentations , potential misdiagnosis ,government efforts prioritizing breast cancer, and the need for a screening program are suggested reasons. Polices should be implemented to encourage opportunistic and periodic check-up for all groups and specially for people who are predisposed to developing colorectal cancer.

Epithelial Head and Neck Cancer (HNC): Including oral tumors ,is the third most frequent tumor in both sexes, accounting for 7.7% of all cancer incidence in this study .Males are affected twice as often as females ,this is similar to national records in Sudan, [12] and more frequent than that in the U.S.A. [5] Rather than cigarette smoking, smokeless tobacco that traditionally used in Sudan and in the Red Sea State in a moist form called toombak , which is widely used by local tribes and by both genders .The nasopharyngeal(24%), hypo pharyngeal (20.7%) ,and oral cavity cancers (17.4%) being the most common subtypes. A significant proportion is diagnosed at an advanced stage. [43]

Esophageal Carcinoma: Ranks as the fifth most frequent tumor in both sexes and the second most frequent tumor in females in this study . and was the third most frequent in previous years in Red Sea State. Esophageal cancer is a fatal disease among the Sudanese population. It is the most reported gastrointestinal (GI) cancers at the Port Sudan Oncology Centre(POC), and constitutes 46.7% of all (GIT) cancers in this study ,females were predominating compared with other neighbouring countries ,with female-to- male ratio was approximately 1.7:1 ;these records were more frequent than those in the U.S.A., and other developed countries, [5] and more frequent than the old local record in 2006[20] but closely matching the national records in Sudan. [44-46] Most patients were females (64%) compared to males (36%)..The disease was more frequent in the age group 59-78 years (51.3%) ,and (40.3%) were in the age group 39-58 years. The a mean age was 55 ±14 years at the time of the diagnosis and is often diagnosed at an advanced stage due to lack of early symptoms and access to healthcare. The most common Tumors were primarily located in the middle (46.4%) and lower esophagus (41.2%). Histopathological analysis revealed SCC as the most frequent subtype (82.2%), followed by ADC (17.4%) ,and one case (.4%) registered as histology adenosquamous , which is a rare type . What is alarming in this study is that certain racial and ethnic groups may have higher risks of developing esophageal cancer. And it is important to mention that the prevalence of esophageal cancer was observed more in specific tribes in this state. More than 78.2% of esophageal cancer occurred among Bani Aamir tribes patients who originally belong to Toker City , Beja tribe (18.4%). , emphasizing the potential influence of genetic or lifestyle risk factors in these populations such as:

(1) Regular consumption of coffee with ginger and pepper (100%) and hot tea (95%) was identified as the most significant risk factors.

(2) GERD in (42.5%) of the patients.

(3) Smoking and alcohol consumption were notably not rare in this region, accounting for only 12 % and 2.5% of cases, respectively. Alcohol Cannot be incriminated as the cause of the high incidence in this study because females who are equally affected rarely take alcohol.

(4) Eating spicy foods and hot drinks ,poor oral health, cigarette smoking,and toombak are widely used among Sudanese males. [43-46] Tobacco nitrosamines may be released during consumption and may account for the high numbers of oral and esophageal tumors. [13,44]

(5) Socioeconomic status: Esophageal cancer patients who had low socioeconomic status, daily diet components are poor, and only a few people have access to fruits and vegetables with high processed red meat. Existing literature presents a complex interplay between dietary factors and esophageal cancer risk. Studies, including Musa et al.,(2021), highlight associations between esophageal cancer, particularly squamous cell carcinoma, and consumption of hot beverages, red meat, and deficiencies in fruit and vegetable intake,

(6) The majority of patients were over 40 years (90%) , and 51.3% of patients over 60years, aligning with the known age as a probable risk factor . .[44,45]

The predominance of esophageal cancer among females in this study may be due to several factors.

(1) The smoke produced by the burning of acacia wood (Acacia nilotica), which is used for cosmetic purposes by married women who practice this ritual frequently. It is unknown if inhalation of this smoke, usually done in an enclosed space and in close proximity to the burning source, has any role as a cancer-causing agent. But never before, to our knowledge, through burning of the wood. Polycyclic aromatic hydrocarbons (PAH) are incomplete combustion by-products and have been pointed out as carcinogenic agents, in particular benzo. Inhalation of the Acacia wood smoke could expose women to PAH. Whether protective, associated with an increased risk of cancer.[47,48]

(2) Previous studies have reported a high prevalence of anaemia and folate deficiency among Pregnant women in Gezira and Eastern Sudan. Iron deficiency may play a role in the occurrence of OC in Gezira, an effect which may be exacerbated in women of reproductive age through blood loss during menstruation and also through repeated pregnancies (average fertility rates in Sudan are 4.6 children per women). [49,50] And it is an important to address as they report exposure to established risk factors significantly less often than men in the general population. Thus, we believe that additional risk factors, not documented to date. Despite the non-modifiable nature of risk factors, it is important to be aware of them and take steps to reduce modifiable above-mentioned risk factors, such as avoiding exposure to carcinogens, getting vaccinated for preventable infections, and participating in routine screenings for early detection and management of cancer. [24] HPV also contributes to head and neck tumors in Sudan. [51,52]

Lymphoma: The uncommonly high prevalence of non-Hodgkin lymphoma is difficult to explain , comprising 89.3% of all malignant lymphoma in this study, the fourth most common cancer in men and the tenth most common in women, and the sixth most frequent tumor in both sexes in this study(5.5%); Males were predominating (67.4 %) and showed a steady increase in incidence throughout the period. These records are similar to the national records in Sudan[53], African records, [54] and international records. [5,55] Although immune suppression has been associated with the development of NHL(Non-Hodgkin lymphoma by HIV), which has become a major health problem in this state with very high records of the infected population .It is emphasized the critical involvement of EPV,CMV, and HIV in the pathogenesis of NHL .The higher rate of EPV and HIV-positive lymphoma in men is the line with previous research showing that immunocompromised individuals have a higher risk of lymphoma [56] ; much still has to be understood about the causes of this disease .The gains are attributable to improve vaccination coverage, antiretroviral therapy for HIV, and prevention of mother-to-child transmission of HIV.

Cervical Carcinoma: Among the most frequent tumor types in females in sub-Saharan Africa. In Red Sea State, cervical cancer was the fifth most diagnosed cancer in women after breast, esophageal, endometrial ,and ovarian cancers, affecting nearly 4.9% of all female patients with cancer in this study and 22.2% of all female genital cancers. The ASR is 3.1 per 100,000 ; however, the incidence rate of cervical cancer in these reports was lower compared with national reports, where the ASR in Sudan is 8.7 per 100,000. [55,57] Compared to the neighboring countries in East Africa, the ASR of cervical cancer in Harare, Zimbabwe (2006 –2010) was 103.8 per 100,000.[58] It was 52.4 per 100,000 in Kampala, Uganda. [59] Furthermore, it was lower than what was reported by West African countries. For example, the ASR of cervical cancer reported in Abidjan, Ivory Coast (2025) was 24.0 per 100,000, and was 30.3 per 100,000 in Abuja, Nigeria. [21,60,61] The highest incidence rate of cervical cancer in this study was observed more in women aged 59 - 78 years with 50.8%, followed by women aged 39-58 years with 34.4% . (middle and advanced age 90% of the cases) unlike the incidence rate in Europe and Scotland which most common cancer in women under the age of 35 [62] High-risk HPV genomes have also

been identified in patients with cervical carcinoma from Sudan. [63,64] Screening and prevention programs may help reduce the number of patients with cervical carcinoma in the future. [64,65] Other tumor types with viral involvement are liver cancer, which accounts for 3.3% of cancer incidence in Port Sudan Oncology Centre(POC) (hepatitis B virus and hepatitis C virus) and nasopharyngeal carcinoma (HPV and EBV). [63-67]

Leukaemia: Ranked as the second most common malignancy at Port Sudan Oncology Centre (POC) . It accounted for 12.4% off all cancers registered by the center. The ASR for leukaemia reported to be around 9.5 per 100,000 in this study. About one third of cases (34.2%) were diagnosed as chronic myelogenous leukaemia (CML),followed by acute myeloid leukaemia (AML)by (19%). This record is similar to national records in Sudan where the national reported ASR for leukaemia is 10.0 per 100,000. [68] But globally the ASR for leukaemia is 5.4 per 100,000. [69]

Cancer Trends in Port Sudan Oncology Centre(POC) :

Through an analysis of recent trends in observed cancer incidence , the following assumptions were raised :

1. Cancer incidence at the Port Sudan Oncology Centre (POC) increased steeply with age, but breast cancer ,colon ,and some esophageal cancer occurred exceptionally early.
2. Note on trends: It may be misleading to focus too much attention on any apparent changes in incidence between 2024 and 2025 as indicative of cancer trend in the Red Sea State. This was during the period of armed conflict and the displacement of patients with cancers to the Red Sea State (21.4% of all new patient records during that period) ; it is more informative to examine trends in incidence observed over a number of years.
3. Striking increase of incidence records of this study compared with old local records(AgeepAK etal). [20] Study of cancer incidence in Red Sea State in 2006 indicates that the Red Sea State is experiencing a growing cancer burden attributed to population growth and aging ,urbanization, lifestyle changes, improvement in patient awareness, and improvement in diagnostic measures. While some cancers, like cervical cancer, and GIT cancer, are decreasing in incidence, others are increasing like lukaemia and NHL due to factors like obesity and viral infection HPV,HIV. Cancer development itself is a complex ,evolutionary process involving multiple genetic and cellular changes occurring over many years.
4. The COVID-19 pandemic has caused disruption in cancer diagnosis and treatment, potentially leading to delays in diagnosis and impacting the cancer statistic in POC.
5. The number of new cases in a year is an indicator of the need for resources for diagnostic investigations and first-line treatment. Similarly, the annual number of cancer deaths is an indicator of the need for resources for palliative and terminal care.
6. The most common age group in men at diagnosis was (59 –78) years, accounting for 47.9%, while the most common age group in women at diagnosis was (39-58) years, accounting for 43.9%. This may, at least in part, be due to the later onset of prostatic carcinoma (median age=59-75 years) compared to breast cancer (median age=35-48years)
7. Infectious agents(HPV,HBV,EPV,HIV), Toombak, smoking tobacco, alcohol, local meals and drinks are most common risk factors. While some risk factors, such as genetics, cannot be modified ,many life style factors, including tobacco and alcohol use, diet, physical activity ,and weight management ,can be modified to reduce the risk of developing cancer.

Conclusion:

Despite the study limitations, the (POC) data gave a fair representation of cancer profile of the Red Sea State. Achieving cancer equity faces numerous barriers and limitations ,include in adequate funding for cancer research, limited cancer education and awareness efforts, insufficient screening and diagnostic facilities, lack of organized and effective cancer registry and access to care, shortage of specialized health care personnel, and high costs of screening ,vaccination and treatment. Addressing of these limitations holistically is important to reduce the risk and improve the prospect of survival of cancer patients ,and reduce the projection of cancer incidence and mortality..

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