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Int J Urol. Author manuscript; available in PMC 2020 January 01.

Published in final edited form as:

Int J Urol. 2019 January ; 26(1): 102–112. doi:10.1111/iju.13824.

An estimate of the incidence of bladder cancer in Africa: a systematic review and Bayesian meta-analysis

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Abstract

Objectives—To quantify the epidemiology of bladder cancer in Africa to guide a targeted public health response and support research initiatives.

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Conflicts of interest statement: The authors declare that they have no conflicts of interests.

Ethics committee approval: This study did not involve any human subjects or animals. All data is from published or summaries of completed data collections.

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Methods—We systematically searched publicly available sources for population-based registry studies reporting the incidence of bladder cancer in Africa between January 1980 and June 2017. Crude incidence rates of bladder cancer were extracted. A Bayesian network meta-analysis model was employed to estimate incidence rates.

Results—The search returned 1,328 studies. Twenty-two studies conducted across 15 African countries met our pre-defined selection criteria. Heterogeneity across studies was high (I^2=98.9%, p<0.001). The pooled incidence of bladder cancer in Africa was 7.0 (95% Credible Interval [CI]: 5.8–8.3) per 100,000 population in men and 1.8 (1.2–2.6) per 100,000 in women. The incidence of bladder cancer was consistently higher in North Africa in both sexes. Among men, we estimated a pooled incidence of 10.1 (7.9–11.9) per 100,000 in North Africa and 5.0 (3.8–6.6) per 100,000 in Sub-Saharan Africa (SSA). In women, the pooled incidence was 2.0 (1.0–3.0) per 100,000 and 1.5 (0.9–2.0) per 100,000 in North Africa and SSA, respectively. Incidence rates increased significantly among men from 5.6 (4.2–7.2) in the 1990s to 8.5 (6.9–10.1) per 100,000 in 2010.

Conclusions—This study suggests a growing incidence of bladder cancer in Africa in recent years, particularly among men and in North Africa. This study also highlights the lack of quality data sources and collection of essential clinical and epidemiological data in several African countries and this maligns public health planning.

Keywords

Africa; Bladder cancer; Schistosoma haematobium; Squamous cell carcinoma; Transitional cell carcinoma

1. Introduction

Bladder cancer is the ninth most common cancer worldwide, with an estimated 430,000 new cases and 165,000 deaths in 2012.[1] Among the leading cancer sites in Africa, there were an estimated 24,437 new cases and 13,268 deaths from bladder cancer in 2012.[1] The risks of bladder cancer appear to vary across world regions, correlating with smoking and occupational exposures to carcinogens in developed countries, and with chronic bladder urothelial irritation from *Schistosoma haematobium infection* in Africa and the Middle East.[2] However, this is changing as several African countries undergo social and economic development and changes. That is, while the histologic sub-type of bladder cancer in most parts of Africa has historically been squamous cell carcinoma (SCC) linked to schistosomiasis, a gradual shift to transitional cell carcinoma (TCC) linked to increased cigarette smoking and other lifestyle changes associated with urbanization and industrialization has been documented.[3,4]

While the general awareness of cancer in Africa continues to increase,[5] health systems are generally fractured and underfinanced and thus cancer screening services supporting early cancer diagnosis and prompt treatment are largely unavailable. For those diagnosed with cancer, a lack of subspecialty training in oncology and essential cancer medicines results in suboptimal management plans and care.[6] Ongoing inadequate sanitation and hygiene also promote the recurrence of urinary schistosomiasis in many parts of Africa.

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In the presence of suboptimal epidemiological data and limited histological data, this study seeks to systematically review and coalesce data on the incidence of bladder cancer in Africa to provide a comprehensive epidemiological report that can guide relevant research and public health policy in the region.

2. Methods

2.1 Search strategy and data sources

We systematically searched Medline, EMBASE, Global Health and African Journals Online (AJOL), the International Association of Cancer Registries (IACR) website, WHO African Region (AFRO) site, *GLOBOCAN studies,*[7–9] "*Cancer Incidence in Five Continents (CI5) series*",[10] "*Cancer in Africa: Epidemiology and Prevention,*"[5] and Google Scholar for population-based registry studies between January 1980 through June 2017 reporting the incidence of bladder cancer in Africa (Table 1). Reference lists of studies were hand-searched to ensure completeness in the data capture.

2.2 Selection criteria

Without language restriction, we included population-based registry studies as defined by IACR (registries that collect data from different sources in the population on all new cancer cases in well-defined populations)[10], conducted in Africa that reported crude estimates of the incidence of the bladder cancer. For inclusion, a study had to have utilized histologically confirmed bladder cancer. We excluded hospital-based reports, studies on non-human subjects, reviews, case reports, opinions or editorials.

2.3 Data extraction

Data extraction was performed by two independent reviewers (AA and RAD) who separately screened studies against the selection criteria (Kappa = 92%). Disagreements were resolved by a third reviewer (DA). Data and other relevant information, including location, period, design, cancer registry, histological confirmation of diagnosis, data collation methods, coding criteria, data ascertainment and modality with which population or person-years at risk were generated, mean age (or age range), cancer cases, and crude incidence were extracted from each study.

2.4 Quality criteria

Studies were assessed for five quality measures (supplementary material):

1. The cancer registration process, which grades how the cancer registries collated and ascertained their data.
2. The coding criteria employed across studies were also reviewed to determine if the cancer types were reported according to the primary anatomic site (topography) or cellular characteristics (morphology—histology, behaviour, and grade) using the international classification of diseases (ICD) and oncology (ICD-O) guidelines.[11–13]
3. How population or person-years at risk was generated in each study.

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4. Whether the population covered in each study was representative of the target (subnational) and,

5. national populations.

Each criterion was scored *one* (1), with studies graded as *high* (4–5), *moderate* (2–3) or *low* (0–1) quality (see Table S1). The quality assessment has been employed in another study.[14]

2.5 Data analysis

A Bayesian network meta-analysis model[15,16] was used to estimate the pooled incidence rates of bladder cancer per 100,000 population from the raw data. This model was selected due to the lack of data across calendar years, age groups, African regions and countries. This modeling approach created hierarchical models and included several covariates without leading to biases due to over-fitting the data. This is possible as the model is based on a combination of information obtained from the bladder cancer data extracted (the likelihood) with a previous known or subjective knowledge (the prior) to generate an update on the process under investigation (the posterior probability). In this approach, we used an extension of the random effects model[17] on the Bayesian meta-analysis models using uninformative priors (i.e., the prior was subjective as this was based on a balance of available data). From the Bayesian model, we extracted a posterior of plausible estimates as contained within the posterior interval 0.05 to 0.95, and averaged them to generate the posterior mean estimate. The posterior mean estimates corresponded to the pooled incidence rates of bladder cancer, and were obtained by averaging over each strata of the posterior distribution of the expectation of likelihood function respectively for all Africa (sorted by sex), African regions, countries, study period, and mean age of the patients. By doing this, we have eliminated all non-plausible values from the tails of the distribution, and averaged only those within the values of the credible interval (CI). To verify that the fit of the Bayesian model appropriately summarizes cancer explanatory variables as contained in our dataset, we conducted a posterior predictive check using (i) graphical inspection of the posterior distribution of the model or nodes effects; (ii) graphical inspection of the observed data and the one generated by the model (marginal distribution of the response variable); (iii) Bayesian tests to verify if the moments of the observed data matches those generated by the model; and (iv) the Watanabe-Akaike or widely applicable information criterion 2 (WAIC2),[18] which is a numerical metric used to measure the predictive accuracy of a fitted Bayesian model, with a lower WAIC2 score indicating better prediction or model fit.[18] All statistical analyses were conducted using the package *rstan* (probabilistic programming language) in the R programming language (see Supporting methods).[19]

3. Results

3.1 Search results

The literature search returned a total of 1,328 publications. Out of these, 1,321 publications were from four databases: PubMed (n=537), EMBASE (n=612), Global Health (n=164) and AJOL (n=8). After all of the studies had been collated and duplicates removed, 812 records remained. Based on article screening, a further 726 studies were excluded, leaving a total of 86 full-text manuscripts to be assessed. After applying the selection criteria, 64 studies were

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excluded (46 articles did not specify study designs and/or clarify their cancer registration process, and 18 studies did not define catchment population). A total of 22 studies were retained for this study (Figure 1, Supporting references).

3.2 Study characteristics

The retained 22 studies were conducted across 15 African countries, with 8 studies retrieved from North Africa, Central Africa (1), East Africa (4), Southern Africa (4), and West Africa (5) (Table 2). The study period across all studies ranged from 1986 to 2010. The mean age across studies ranged from 36.8 years to 61 years, with subjects mostly in the 50–59-year age group (60%), followed by the 40–49-year age group (30%). Fifteen studies (68%) were graded as high quality (Table S1).

3.3 Bayesian network modelling

Significant associations were observed between the incidence of bladder cancer and increasing age, gender and African sub-region (Prob>F = 0.0003, adjusted R-squared = 39.7%). All the Bayesian networks models showed agreement with the scale of the observed datasets (Figure 2 and Figure 3) however we used Model 6 presented in the supplement due to the model fit statistics (Table 3, i.e. has the lowest WAIC2 score), to generate the reported estimates (Figure S1).

3.4 Pooled incidence rate of bladder cancer in Africa

3.4.1 Continent-wide—Across African regions, variations were observed in the reported incidence of bladder cancer, with high heterogeneity estimated across studies (I^2=98.9%, p<0.001). The pooled crude incidence of bladder cancer in Africa was significantly higher among men compared to women, with incidence estimated at 7.0 (95% CI: 5.8–8.3) per 100,000 population per year in men, and 1.8 (95% CI: 1.2–2.6) per 100,000 in women (Table 4).

3.4.2 Regions—The incidence of bladder cancer was consistently higher in North Africa in both sexes. Among men, we estimated a pooled incidence of 10.1 (95% CI: 7.9–11.9) per 100,000 in North Africa and 5.0 (95% CI: 3.8–6.6) per 100,000 in Sub-Saharan Africa (SSA). In women, the pooled incidence was 2.0 (95% CI: 1.0–3.0) per 100,000 and 1.5 (95% CI: 0.9–2.0) per 100,000 in North Africa and SSA, respectively. Among men in SSA, Southern Africa had a relatively higher incidence at 7.1 (95% CI: 4.7–9.7) per 100,000 followed by West Africa at 4.5 (95% CI:2.9–7.3) per 100,000, while the incidence in Central, and East Africa were 3.8 (95% CI: 0.9–9.4), and 3.5 (95% CI: 2.7–5.4) per 100,000, respectively. Among women, the incidence across SSA sub-regions were comparable, with Central, East, Southern and West Africa having 1.3 (95% CI: 0.4–2.5), 1.7 (95% CI: 1.1–2.5), 1.5 (95% CI:0.8–2.6), and 2.0 (95% CI:1.3–2.9) per 100,000, respectively (Table 4, Figure 4 and Figure 5).

3.4.3 Time-trends and age-groups—Among men, the incidence of bladder cancer increased from 5.6 (95% CI: 4.2–7.2) in the 1990s to 8.5 (95% CI: 6.9–10.1) per 100,000 in 2010. Among women, a minimal decrease in incidence was observed over the same period. Meanwhile, increase in bladder cancer incidence was also observed with advancing age

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among men, with incidence increasing from 4.8 (95% CI: 1.9–11.9) per 100,000 among persons aged 30–39 years to 13.3 (95% CI: 9.7–15.5) per 100,000 among persons aged 60 years and above. The incidence rates were however comparable between these age groups among women (Table 4).

4. Discussion

This study assembled a range of diverse datasets, mainly population-based cancer registries, to provide continent-wide and sub-regional estimates of bladder cancer in Africa. Our findings show a significantly higher incidence of bladder cancer among men (7.0 per 100,000) compared to women (1.8 per 100,000). This approximately 4:1 disparity in disease incidence has been observed in other settings and cohort studies.[1,20] In addition, our estimates, which use a different statistical method, are comparable to the 2012 GLOBOCAN estimates where the male and female bladder cancer incidence was 6.3 and 2.1 per 100,000 population, respectively,[21] (Table 4). This sex difference is presumably driven to some extent by differences in cigarette smoking, although the rates of cigarette smoking is rapidly increasing among both sexes across Africa,[22–24] as there does not appear to be a sex-specific difference in the likelihood of *S. hematobium* infection.[4,25] Dobruch et al[26] reported that several biologic and epidemiologic factors underlie gender differences in bladder cancer incidence, although women, despite a relatively lower incidence rate, particularly present with advanced tumours at diagnosis and higher mortality rates owing to delays in urologic evaluations. Meanwhile, we observed an increase in the incidence of bladder cancer among men from 5.6 to 8.5 per 100,000 between 1990 and 2010.

We noted a consistently higher bladder cancer incidence in North Africa in both sexes. Our estimates again are similar to those reported by GLOBOCAN[21] and the Global Burden of Disease (GBD) collaborators.[27] For example, in 2012, GLOBOCAN estimated a bladder cancer incidence at 15.1 and 3.0 per 100,000 among men, and 3.2 and 1.6 per 100,000 among women, for North Africa and SSA, respectively;[21] and the GBD collaborators also estimated an overall incidence of bladder cancer at 8.3 and 5.3 per 100,000, respectively, for the two regions[27] (Table 4). Indeed, bladder cancer incidence rates in SSA have been reported as among the lowest in the world, but the North African estimates are actually comparable with incidence rates obtained in Europe (18.0 per 100,000), Middle East (17.2 per 100,000), and the Americas (12.9 per 100,000).[1,21] Bladder cancer is regarded as the most common malignancy in Egypt, constituting over 30% of cancers.[28] The higher rates in Egypt, and North Africa generally, has been linked to the proximity with the Nile delta region where *S. Hematobium* infection is widespread, and increased cigarette smoking.[25] In contrast to other world regions, South-East Asia and Western Pacific regions reportedly have lower bladder cancer incidence at 2.0 and 3.5 per 100,000, respectively.[21]

A strength of this paper is a breakdown of cancer incidence across SSA regions, study periods, and age groups, which to the best of our knowledge, is the first study on bladder cancer incidence offering such detail. We found that the Southern Africa region had a relatively higher bladder cancer incidence at 7.1 per 100,000, compared to other SSA regions. While there are no clearly comparable estimates, Antoni et al[1] noted that women from Malawi had the second highest incidence rate of bladder cancer in their study at 9.2 per

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100,000. The reasons for these regional differences in SSA are not clear, however the presence of several riverine communities favouring breeding of *Schistosoma* species appear to be a key factor.[25]

Owing to its association with schistosomiasis and the inability of African countries to effectively halt the breeding and transmission of Schistosoma species, bladder cancer has been called a 'neglected tropical disease'.[25,29] Although the World Health Organization supported the Schistosomiasis Control Initiatives (SCI) introduced across African states in 2002, the programme has been ineffective in many SSA regions due to incomplete drug distribution resulting in insufficient population coverage, particularly of infants and pre-school children who suffer disproportionately from *Schistosoma* infection.[29] Primary prevention may be the cheapest and most effective public health response to bladder cancer in Africa, particularly by intensifying eradication programmes for schistosomiasis through widespread praziquantel therapy, provision of potable water and appropriate sanitation measures.

Suboptimal control of primary exposures for bladder disease is further confounded by an absence of widespread population-based cancer screening programmes. This contributes to a late presentation of cases, usually marked with a low probability of curative treatment.[4] Many urology centres still lack basic cystoscopy equipment, and there are limited skilled personnel and training facilities to support 'basic' surgeries like the transurethral resection of bladder tumor (TURBT).[2,20]

Despite attempts to provide a representative and comprehensive report on the incidence of bladder cancer in Africa, the lack of data from many countries remain a major limitation of this study. Moreover, many studies were conducted in sub-national population-based cancer registries, mainly covering provinces, districts or major cities within a country. This is even marked in Central Africa with only one study selected from this region. These geographic and demographic differences are reflected in our estimate of heterogeneity (I^2>98%, p<0.001). Further, variations in study designs, cancer registration, coding and abstracting, and the estimation of cancer incidence are important sources of heterogeneity which hinder several active disease assessment efforts. Another important source of heterogeneity may be due to the differences in tumor subtypes (SCC/TCC), which we could not ascertain from the available data. Moreover, we could not specifically describe the smoking prevalence and rates of schistosomiasis infection across population groups and how these relate to variations in bladder cancer incidence in African sub-regions. Another limitation of this study is the inability to estimate age-standardized rates of bladder cancer incidence on the continent. This is mainly due to the lack of data on age from many studies. We could also have missed some important findings by excluding hospital-based studies, however, considering that several hospital-based reports do not clearly define population covered or person-years at risk, we believe including these studies may affect the overall representativeness of our estimates.

These limitations aside, our findings offer the closest possible representation of the incidence of bladder cancer in Africa considering available data. To augment the contribution of our work, we have provided all our data to support future efforts by others. It

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is our hope that these findings may encourage policy redirection and resource allocation towards improved primary prevention, early diagnosis, improved research and capacity building targeted at bladder cancer on the continent.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Role of the funding source: There was no funding source for this study. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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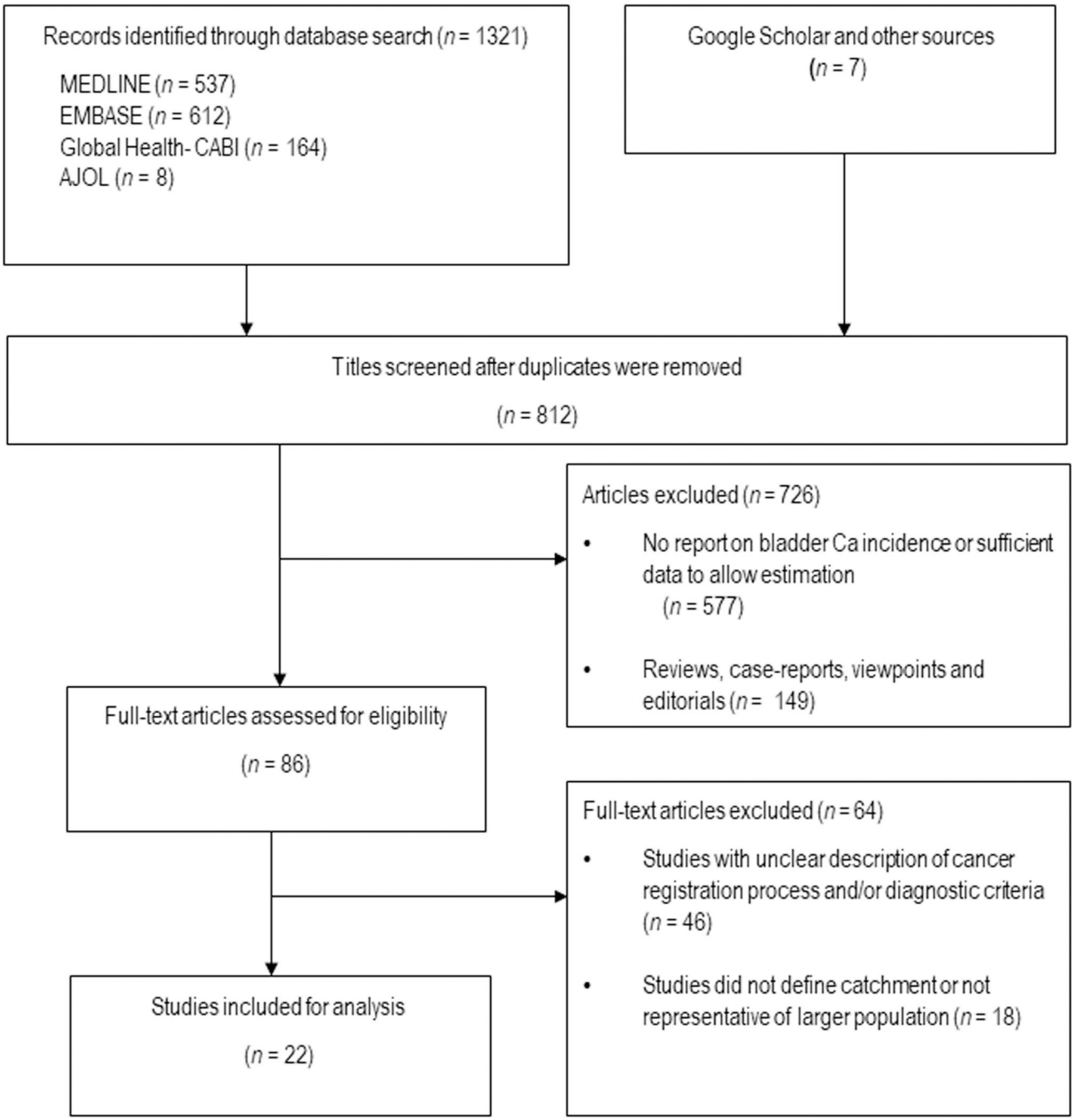

Figure 1.
Flow chart of study selection.

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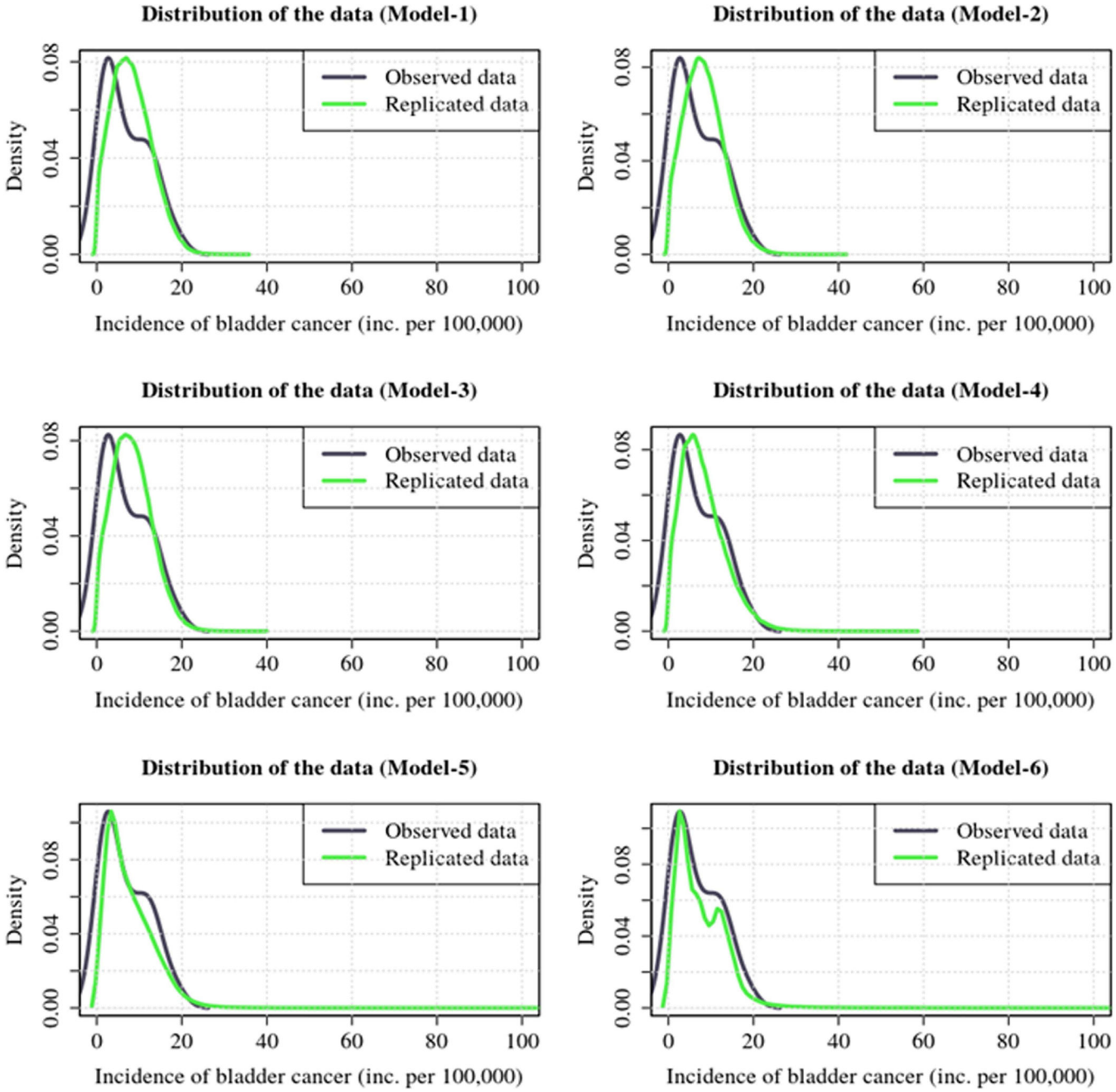

Figure 2.
Bayesian modelling showing matched data distribution (Men)

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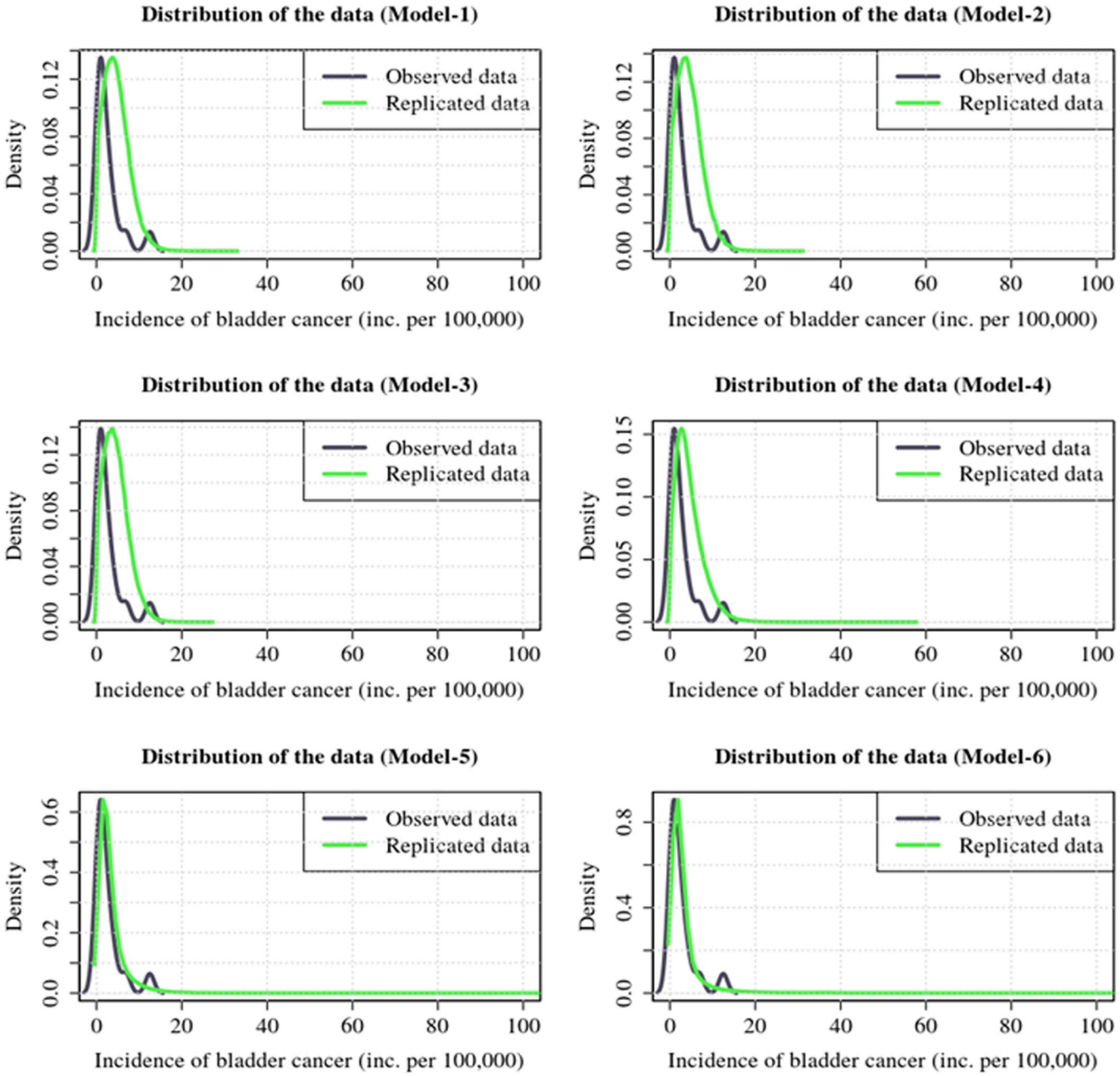

Figure 3.
Bayesian modelling showing matched data distribution (Women)

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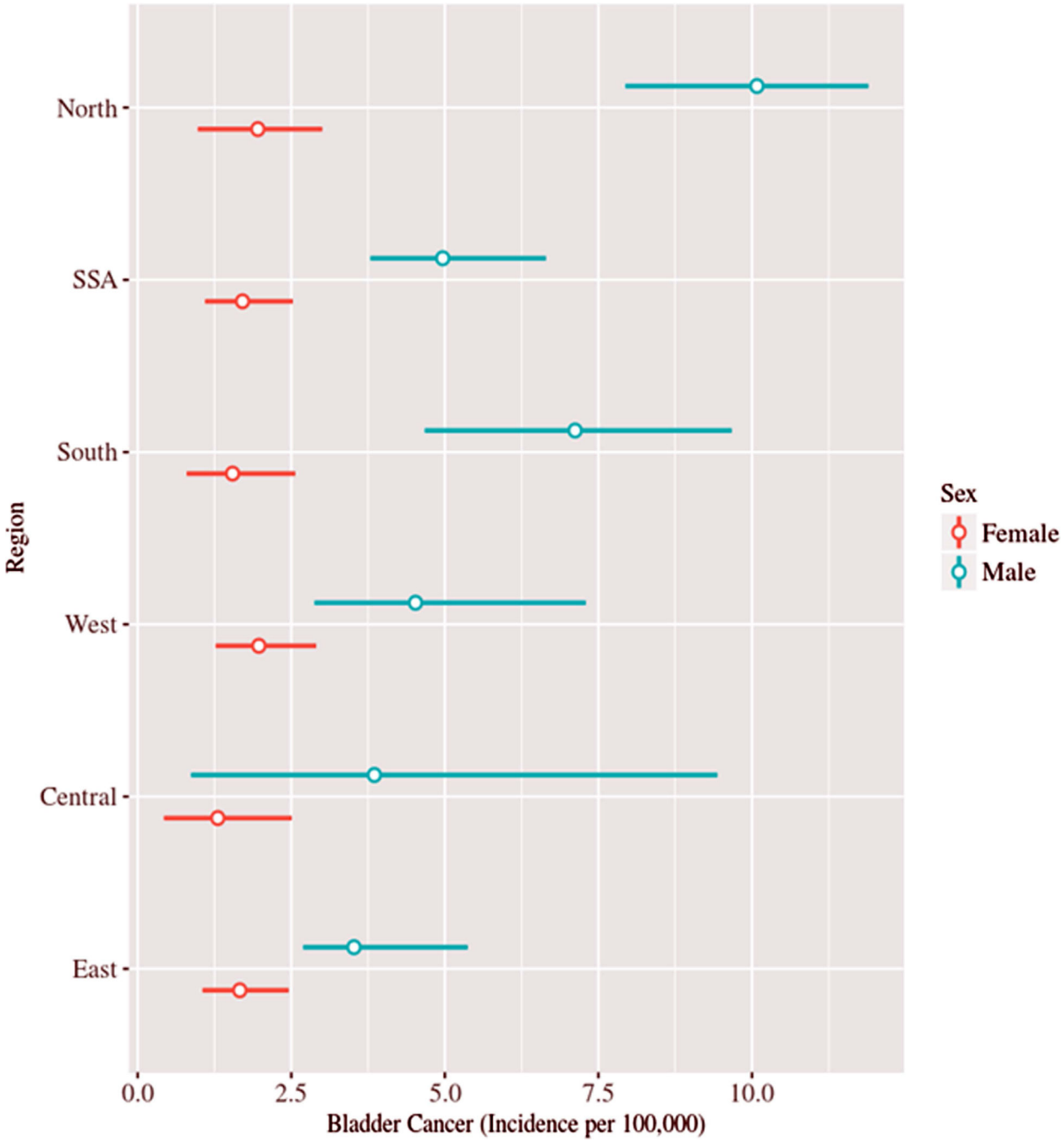

Figure 4.
Pooled bladder cancer incidence by African region

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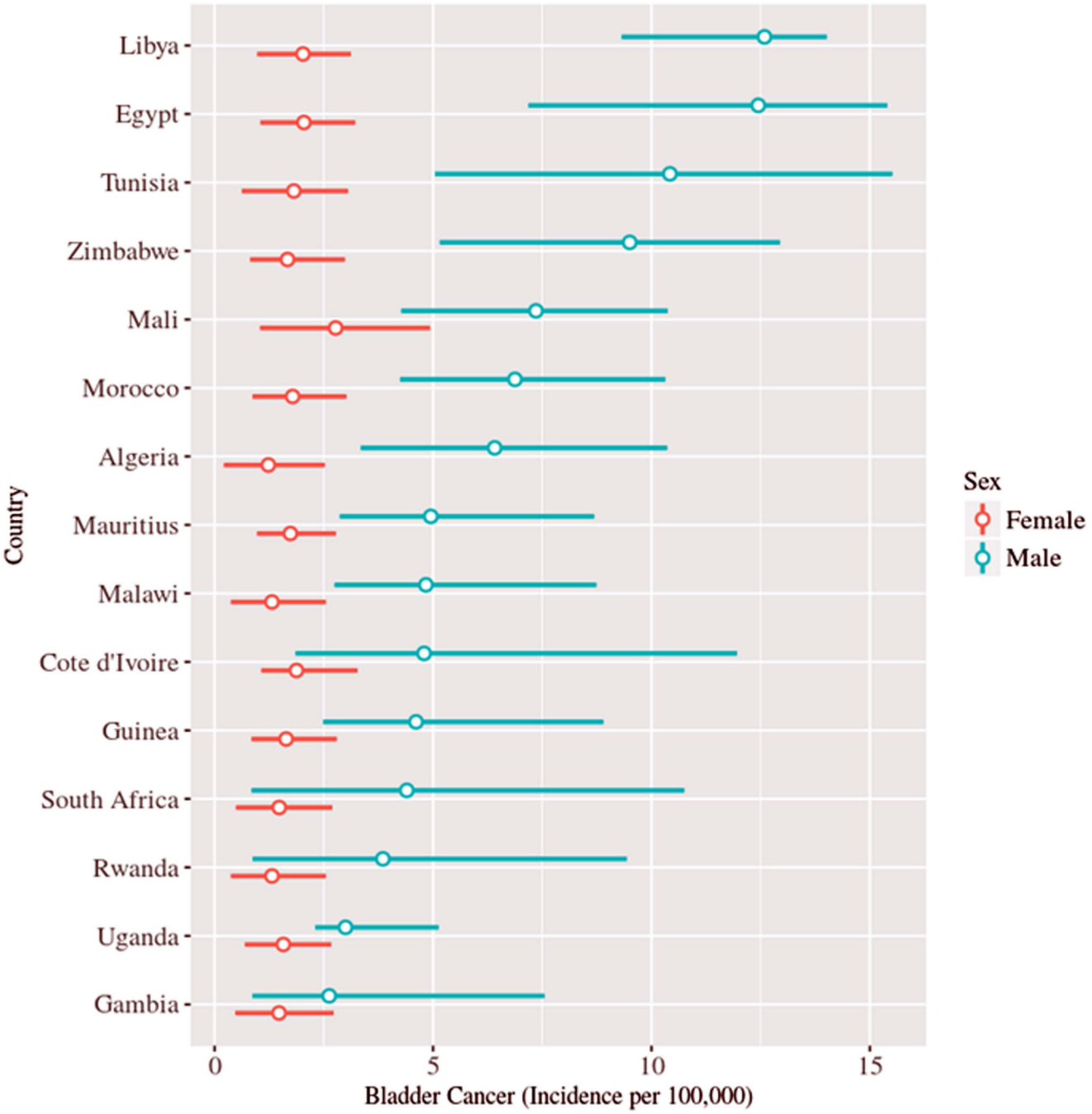

Figure 5.
Pooled bladder cancer incidence by African country

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Table 1.

Search terms for studies on bladder cancer in Africa (MEDLINE)*

#	*Searches*
1	africa/ or africa, northern/ or algeria/ or egypt/ or libya/ or morocco/ or africa, central/ or cameroon/ or central african republic/ or chad/ or congo/ or "democratic republic of the congo"/ or equatorial guinea/ or gabon/ or africa, eastern/ or burundi/ or djibouti/ or eritrea/ or ethiopia/ or kenya/ or rwanda/ or somalia/ or sudan/ or tanzania/ or uganda/ or africa, southern/ or angola/ or botswana/ or lesotho/ or malawi/ or mozambique/ or namibia/ or south africa/ or swaziland/ or zambia/ or zimbabwe/ or africa, western/ or benin/ or burkina faso/ or cape verde/ or cote d'ivoire/ or gambia/ or ghana/ or guinea/ or guinea-bissau/ or liberia/ or mali/ or mauritania/ or niger/ or nigeria/ or senegal/ or sierra leone/ or togo/
2	exp vital statistics/ or exp incidence/
3	(incidence* or prevalence* or morbidity or mortality).tw.
4	(disease adj3 burden).tw.
5	exp "cost of illness"/
6	exp quality-adjusted life years/
7	QALY.tw.
8	Disability adjusted life years.mp.
9	(initial adj2 burden).tw.
10	exp risk factors/
11	2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10
12	exp bladder cancer/
13	1 and 11 and 12

*Search terms are for MEDLINE. Searches in other databases are relatively similar.

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TABLE 2.

Study characteristics

Author[*]	*Country*	*Study period*	*African region*	*Registry*	*Registry data collation methods*	*Quality grading*	*Cases (male)*	*Incidence rate/ 100000 (male)*	*Cases (female)*	*Incidence rate/ 100000 (female)*
Echimane et al.	Cote d'Ivoire	1995–1997	West	Abidjan Cancer Registry (population-based)	Data were actively collated from public and private hospitals and pathology laboratories	Moderate	23	2.2	18	1.8
Bah et al.	Gambia	1988–1997	West	Gambia National Cancer Registry (population-based)	Data were actively collated from public and private hospitals and pathology laboratories	High	21	1	-	-
Sighoko et al.	Gambia	1998–2006	West	National Population-based Cancer Registry	Data were actively collated from public and private hospitals and pathology laboratories	High	29	0.9	8	0.21
Koulibaly et al.	Guinea	1992–1995	West	Guinea Cancer Registry (population-based)	Active search for cancer cases in public and private hospitals, pathology services, and autopsy reports	Moderate	25	3.8	7	0.9
El Mistiri et al.	Libya	2003	North	Benghazi Cancer Registry	Active searching of hospitals, public and private laboratories, and death certificates	High	49	11.7	6	1.3
El Mistiri et al.	Libya	2004	North	Benghazi Cancer Registry	Active searching of hospitals, public and private laboratories, and death certificates	High	59	12.4	16	4.5

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*Author**	*Country*	*Study period*	*African region*	*Registry*	*Registry data collation methods*	*Quality grading*	*Cases (male)*	*Incidence rate/ 100000 (male)*	*Cases (female)*	*Incidence rate/ 100000 (female)*
Banda et al.	Malawi	1994–1998	South	Malawi National Cancer Registry (population-based)	Combination of active and passive methods of case finding. The registry receives copies of reports on all cancer cases diagnosed in a central pathology laboratory, registry staff regularly visit inpatient wards and oncology outpatient clinics of national hospital, and seven other private and faith-based hospitals in the district.	Moderate	36	4.3	3	0.3
Somdyala et al.	South Africa		South	Population-based cancer registry of the Eastern Cape Province, South Africa	Active and passive case finding of new cancer cases across health centres, district and referral hospitals and their laboratories	High	9	0.6	7	0.3
Missaoui et al.	Tunisia	1993–2006	North	The population-based cancer registry of the centre of Tunisia	Proactive data collection from the pathology units of the public and private medical centres, and the departments of Radiotherapy, Oncology and Haematology of the University Hospital of Sousse	High	478	18.5	4	0.2

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*Author**	*Country*	*Study period*	*African region*	*Registry*	*Registry data collation methods*	*Quality grading*	*Cases (male)*	*Incidence rate/ 100000 (male)*	*Cases (female)*	*Incidence rate/ 100000 (female)*
Parkin et al.	Uganda	1991–2006	East	Kampala Cancer Registry (population-based)	Data collected from several sources within Kyadondo county--screening pathology reports from government hospitals and private pathology laboratories; and conducting regular searches for cancer cases admitted or treated in hospitals.	High	134	2.9	81	1.6
Wabinga et al.	Uganda	1991–1997	East	Kampala Cancer Registry (KCR)	Active and passive case finding of new cancer cases across public and private hospitals and pathology laboratories	High	13	2.5	-`	-
Wabinga et al.	Uganda	1991–2010	East	Kampala Cancer Registry (KCR)	Active and passive case finding of new cancer cases across public and private hospitals and pathology laboratories	High	10	2.9	-	-
Chokunonga et al.	Zimbabwe	1993–1995	South	Zimbabwe National Cancer Registry	Data collated from all public and private hospitals and pathology laboratories	High	62	8.9	39	6.9
Basset et al.	Zimbabwe	1990–1992	South	Zimbabwe National Cancer Registry (population-based)	Data are collected from all hospital services in the city, from pathology	High	68	13.2	43	12.5

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Author*	Country	Study period	African region	Registry	Registry data collation methods	Quality grading	Cases (male)	Incidence rate/ 100000 (male)	Cases (female)	Incidence rate/ 100000 (female)
					laboratories (public and private), and from death certificates.					
Bayo et al.	Mali	1987–1998	West	Population cancer registry in Bamako, Mali	Data collated from all public and private hospitals and pathology laboratories	High	23	7.5	12	3.2
*Newton et al*1	Rwanda	1991–1994	Central	Population-based cancer registry in the southern prefecture of Butare, Rwanda	Active and passive case finding of new cancer cases across public and private hospitals and pathology laboratories	Moderate	5	0.9	3	0.4
Manraj et al.	Mauritius	1989–1993	East	National cancer registry	Systematic registration of cancer cases identified from central laboratory of Hospitals, admissions registers and discharge résumés	Moderate	114	4.4	44	1.7
Fedewa et al.	Egypt	1999–2002	North	Gharbiah Population-Based Cancer Registry	Collated from relevant health institutions across the region	High	977	13.7	232	3.2
Bouchbika et al.	Morocco	2005–2007	North	Casablance Registry	Greater Casablanca Cancer Registry	Moderate	368	6.7	52	0.9
El Mistiri et al.	Libya	2003–2005	North	Benghazi Cancer Registry	Active searching of hospitals, public and private laboratories, and death certificates	High	174	15.2	26	2.3

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*Author**	*Country*	*Study period*	*African region*	*Registry*	*Registry data collation methods*	*Quality grading*	*Cases (male)*	*Incidence rate/ 100000 (male)*	*Cases (female)*	*Incidence rate/ 100000 (female)*
Hamdi Cheriff et al.	Algeria	1986–2010	North	Population-based Cancer Registry of Setif	Active searching of hospitals, public and private laboratories, and death certificates	High	262	10.3	34	1.2
Hsairi et al.	Tunisia	1993–1997	North	Cancer registries of the regions of the North, Sousse and Sfax	Active search of hospital and laboratory registers in the three regions	Moderate	276	10.7	-	-

Note: Data reported for the last year of study (or single site) when pooled data is not available for multiple year (or site) studies

*see Supplementary material for references.

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Table 3.

Comparative data score statistics of the Bayesian models

Sex	Models	p-values (max)	p-values (min)	p-values (median)	p-values (mean)	p-values (sd)	Eff. N. of parameters	WAIC2
Men	Model-1	0.4	0.6	1.0	0.9	0.2	4.5	137.5
	Model-2	0.4	0.7	1.0	0.9	0.1	5.3	140.9
	Model-3	0.4	0.7	1.0	0.9	0.1	6.7	138.7
	Model-4	0.5	0.6	1.0	0.9	0.3	5.3	138.1
	Model-5	0.5	0.6	1.0	0.8	0.4	9.7	132.5
	Model-6	0.5	0.6	0.9	0.8	0.4	28.4	118.0
Women	Model-1	0.2	0.8	1.0	1.0	0.3	4.7	96.9
	Model-2	0.2	0.7	1.0	1.0	0.2	5.0	96.5
	Model-3	0.1	0.8	1.0	1.0	0.2	4.9	95.1
	Model-4	0.3	0.8	1.0	1.0	0.4	4.5	92.8
	Model-5	0.3	0.7	1.0	0.8	0.3	7.7	77.2
	Model-6	0.4	0.7	0.8	0.7	0.4	15.5	70.0

Note: WAIC2- Watanabe-Akaike or widely applicable information criterion, showing the predictive accuracy of the fitted Bayesian model, with a lower WAIC2 score indicating better prediction [24].

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Table 4.

Pooled incidence rate of bladder cancer in Africa

		Men (incidence per 100,000)				Women (incidence per 100,000)			
		Current study				Current study			
Data	Regions	Posterior mean estimate* (95% CI)	I^2 (%), p value	GLOBOCAN 2012 estimate	GBD 2015 estimate	Posterior mean estimate* (95% CI)	I^2 (%), p value	GLOBOCAN 2012 estimate	GBD 2015 estimate
Africa	Africa	7.0 (5.8–8.3)	99.0, 0.000	6.3	-	1.8 (1.2–2.6)	95.8, 0.000	2.1	-
African Region	North	10.1 (7.9–11.9)	99.4, 0.000	15.1	13.9	2.0 (1.0–3.0)	97.3, 0.000	3.2	2.6
	SSA	5.0 (3.8–6.6)	95.0, 0.000	3.0	7.9	1.7 (1.1–2.5)	94.2, 0.000	1.6	3.2
	Central	3.9 (0.9–9.4)	-	2.2		1.3 (0.4–2.5)	-	1.3	2.9
	East	3.5 (2.7–5.4)	72.8, 0.000	3.3	6.1	1.7 (1.1–2.5)	0.0, 0.748	2.0	2.7
	South	7.1 (4.7–9.7)	97.7, 0.000	7.5	13.3	1.5 (0.8–2.6)	96.1, 0.000	1.9	5.1
	West	4.5 (2.9–7.3)	89.0, 0.000	2.1	8.5	2.0 (1.3–2.9)	89.0, 0.000	1.3	3.2
Year	1980–1989	6.9 (4.7–9.6)	96.6, 0.000	-	-	2.8 (1.0–4.9)	93.2, 0.000	-	
	1990–1999	5.6 (4.2–7.2)	99.5, 0.000	-	-	1.6 (1.0–2.6)	97.0, 0.000	-	
	2000–2010	8.5 (6.9–10.1)	99.0, 0.000	-	-	1.8 (0.9–2.7)	95.8, 0.000	-	
Age	30–39	4.8 (1.9–12.0)	86.5, 0.000	-	-	1.9 (1.1–3.3)	-	-	
	40–49	3.5 (1.9–6.5)	98.7, 0.000	-	-	1.7 (0.9–2.6)	93.8, 0.000	-	
	50–59	7.4 (5.9–8.9)	36.8, 0.208	-	-	1.9 (1.1–2.8)	96.6, 0.000	-	
	60–69	13.4 (9.7–15.5)	99.0, 0.000	-	-	-	95.8, 0.000	-	
Country	Algeria	6.4 (3.3–10.4)	99.8, 0.000	10.8	5.5	1.2 (0.2–2.5)	-	1.5	1.7
	Cote d'Ivoire	4.8 (1.9–12.0)	-	1.7	5.0	1.9 (1.1–3.3)	-	0.5	4.1
	Egypt	12.4 (7.2–15.4)	-	21.8	22.4	2.0 (1.0–3.2)	-	5.6	4.1
	Gambia	2.6 (0.9–7.6)	0.0, 0.744	1.1	4.4	1.5 (0.5–2.7)	-	0.5	1.8
	Guinea	4.6 (2.5–8.9)	-	1.4	10.2	1.6 (0.8–2.8)	-	0.5	2.2
	Libya	12.6 (9.3–14.0)	47.0, 0.152	15.3	28.4	2.0 (1.0–3.1)	71.5, 0.30	2.3	4.0
	Malawi	4.8 (2.7–8.7)	-	8.4	17.4	1.3 (0.4–2.5)	-	5.9	8.0
	Mali	7.4 (4.3–10.4)	-	7.5	16.6	2.8 (1.0–4.9)	-	6.0	5.8
	Mauritius	5.0 (2.9–8.7)	-	7.7	9.4	1.7 (1.0–2.8)	-	1.8	2.5
	Morocco	6.9 (4.2–10.3)	-	10.8	12.7	1.8 (0.9–3.0)	-	1.3	3.2

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		Men (incidence per 100,000)				Women (incidence per 100,000)			
		Current study				Current study			
Data	Regions	Posterior mean estimate* (95% CI)	I^2 (%), p value	GLOBOCAN 2012 estimate	GBD 2015 estimate	Posterior mean estimate* (95% CI)	I^2 (%), p value	GLOBOCAN 2012 estimate	GBD 2015 estimate
	Rwanda	3.9 (0.9–9.4)	-	4.8	5.7	1.3 (0.4–2.5)	-	2.5	2.3
	South Africa	4.4 (0.8–10.8)	-	8.2	12.5	1.5 (0.5–2.7)	-	2.0	4.9
	Tunisia	10.4 (5.0–15.5)	98.1, 0.000	15.3	18.7	1.8 (0.6–3.1)	-	1.7	2.0
	Uganda	3.0 (2.3–5.1)	0.0, 0.862	0.4	6.2	1.6 (0.7–2.7)	-	1.3	2.8
	Zimbabwe	9.5 (5.2–12.9)	79.2, 0.028	2.8	20.4	1.7 (0.8–3.0)	84.5, 0.011	3.0	7.7

* posterior mean est. corresponds to the incidence of bladder cancer estimated in the current study