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Burden of Invasive Candidiasis in West Africa: A Systematic Review and Meta-Analysis

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Abstract

Invasive candidiasis (IC) is an emerging opportunistic fungal infection associated with high mortality among hospitalized patients. Although the epidemiology of IC is progressively changing worldwide, the trend in Africa still needs to be established. This review aimed to evaluate the epidemiology of IC in Western region of Africa. A comprehensive literature search was performed on major electronic databases to identify relevant articles. DerSimonian and Laird random-effects model was used to pool overall prevalence and estimated incidence data. We identified 1975 articles, among which 23 met our inclusion criteria for the systematic review. Available data showed that only 50% (8/16) of West African countries were reported data on IC and only 25% reported at least one laboratory confirmed IC case. The global prevalence of candidemia and non-candidemic deep-seated candidiasis were 0.35% [95% CI 0.23; 0.47] and 0.32% [95% CI 0.00; 2.03], respectively. Among clinical IC cases, only 5.21% were reported before 2010, while 50.08% were reported in the past 5 years. The pooled estimated incidence was 5.55/100,000 [95% CI 5.46; 5.64] and 1.15/100,000 [95% CI

1.11; 1.19, 95% CI]/inhabitants for candidemia, and *Candida* peritonitis, respectively. The case fatality rate was 57.58%. Low gestational age, exposure to broad-spectrum antibiotics and invasive procedures were associated with a higher risk of IC in newborn patients. *Candida albicans* (32.98%) was the most common causative species of IC followed by *C. tropicalis* (11.34%) and *C. parapsilosis* (6.19%). This study showed the scarcity of IC data in western region of Africa and the existence of undiagnosed IC cases.

Keywords

Invasive Candidiasis, Epidemiology, West Africa, Meta-Analysis

1. Introduction

Invasive candidiasis (IC) is a broad term related to the bloodstream or deep-seated organ infection with a yeast of the *Candida* genus [1]. An increasing incidence marks the epidemiology of this infection due to the rising number of patients with predisposing medical conditions such as immunosuppression, broad-spectrum antibiotics, neutropenia, extreme age, abdominal surgery, malignancy, and stay in the intensive care unit [2]-[5]. The global incidence of IC is recently estimated at 1,565,000 people, with 995,000 deaths each year [6]. In addition, bloodstream *Candida* infection is ranked first among invasive fungal infections and fourth among healthcare-associated infections in hospitals in the USA [7]-[9]. The majority of IC cases (about 90%) are traditionally caused by five species (*C. albicans*, *Nakaseomyces glabratus*, *C. tropicalis*, *C. parapsilosis*, and *Pichia kudriavzevii*) [10] [11] and an emergence resilient species *Candida auris* [12] [13]. These six main *Candida* species have been included in the World Health Organisation (WHO) fungal priority pathogens list due to their public health importance and the need to enhance the global response to fungal infection and antifungal resistance [14].

Despite progress in antifungal therapy in recent decades, the mortality rate of IC remains very high (63.6%) [6]. This high mortality should be attributable to many factors, including the delayed diagnosis and initiation of adequate therapy [2] [15] [16]. In addition, the emergence of antifungal resistance to *C. albicans* associated with the epidemiological shift to non-*albicans Candida* species exhibiting intrinsic antifungal resistance, could worsen the prognosis of this invasive fungal infection (IFI) [17].

While there is a growing burden of IC globally, data in resource-constrained countries like those of sub-Saharan Africa are scarce due to limited diagnostic tools, a low index of IC suspicion and, above all, a low level of practitioners' awareness of the life-threatening nature of this invasive fungal disease. Indeed, a Nigerian study reported that only 0.002% (2/1046) of physicians had a good awareness of IFIs [18].

Against this backdrop, this review scrutinized the available data on IC in the West African region, focusing on its epidemiology, diagnostic, and therapeutic management.

2. Methods

2.1. Data Sources and Research Strategy

This review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [19]. The systematic review protocol was registered in the international prospective register of systematic reviews (PROSPERO) with the registration number CRD42021259357.

The search has been performed on major medical electronic databases, including PubMed, Embase, and Scopus.

A comprehensive search strategy was executed to identify all relevant studies addressing IC in West Africa countries from inception to 09 June 2024. The search was limited to English and French language publications. Electronic searches on the selected databases were performed with the following keywords: "Invasive candidiasis", "Candidemia", "Severe candidiasis", "*Candida* bloodstream infection", "Systemic candidiasis", "Africa", "West Africa", and "Africa, Western". The Boolean operators "AND" and "OR" combined these keywords.

In addition to database searching, manual checking has been performed in reference lists of identified articles. The detailed search strategy is described in the **Appendix** (**Tables A1-A3**).

2.2. Eligibility Criteria

Studies were included if they estimated incidence of IC in West African population; or if they included laboratory-confirmed cases of IC cases in west Africa country, regardless the diagnostic method (culture or non-culture).

Studies were excluded if they were commentary or if the study population was outside west Africa.

2.3. Study Selection, Data Extraction, and Data Synthesis

After removing duplicates, two review authors (SND, IWY) independently screened the titles and abstracts of the retrieved articles from the databases. Full text of retained articles were assessed to make final decision regarding eligibility criteria. Disagreements between the two investigators were resolved by discussion and consensus.

In each retained study, the following data were extracted: author name, year of publication study country, study design, clinical form, incidence/prevalence, study population, predisposing conditions, diagnostic methods, *Candida* species, antifungal testing methods, therapeutic management, and outcome.

2.4. Statistical Analysis

A DerSimonian and Laird random-effects model for meta-analysis were used to obtain the pooled prevalence and incidence [20]. The included studies were divided into two groups according to epidemiological indicators (incidence or prevalence). The Freeman-Tukey double arcsine transformation method was used to address variance instability [21]. Confidence intervals were calculated using the Clopper-

Pearson method. Incidences (per 100,000 inhabitants) were utilized for population-based studies, and prevalence (per 100 patients) for hospital-based studies.

Cochran's *Q* statistic and heterogeneity squared index (I^2) were used to assess the heterogeneity between studies. Subgroup analysis was performed to determine the possible sources of heterogeneity, such as the clinical form of *IC*. Heterogeneity between studies was classified as low, moderate, and high when the I^2 value was below 25%, between 25% and 75%, and above 75%, respectively [22].

Potential publication biases were assessed using Funnel plots, but no test of asymmetry was calculated for subgroup analysis [23]. Data were analysed using the packages '*meta*', '*metabias*' *and* '*metafor*' within the statistical software Rstudio (Version 2024.04.2+764).

3. Results

3.1. Search Results

The electronic database search in PubMed, Embase and Scopus retrieved 1966 citations. Nine additional citations were retrieved from the lists of references of eligibles articles. After removing duplicates, 467 citations were considered for title and abstract screening. Then, after screening, 443 citations were excluded based on eligibility criteria. Finaly 23 articles were included in the systematic review (**Figure 1**).

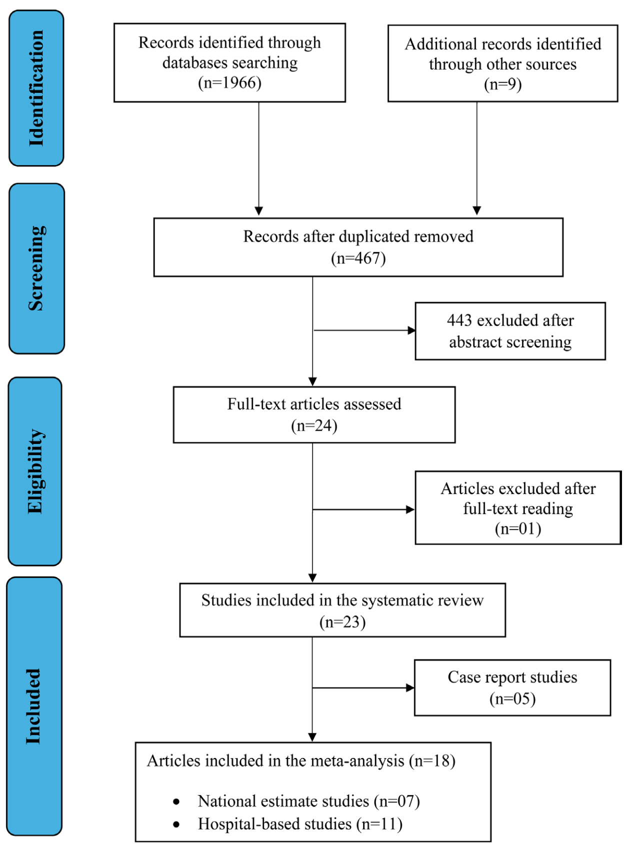

Figure 1. PRISMA flowchart of the selection steps of included studies.

3.2. Epidemiology

3.2.1. Overall Data

Available data showed that IC data was reported for half (8 out of 16) of the West African countries. National estimated incidence of IC was retrieved in 7 countries while four countries reported at least one laboratory confirmed case of IC. Sixteen clinical studies were found including five case studies (all from Nigeria) [24]-[28] and eleven cross sectional studies from Nigeria (5), Cote d'Ivoire (3), Ghana (2) and Gambia (1) [29]-[39]. Only 5.2% of invasive candidiasis cases were reported before 2010 and over 50% been reported during the last 5 years. The population-based studies were conducted in seven countries: Burkina Faso, Cote d'Ivoire, Ghana, Mali, Nigeria, Sierra Leone and Togo [40]-[46].

3.2.2. Meta-Analysis Results

Only the 11 cross-sectional studies [29]-[39] and the seven population-based studies were included for the meta-analysis [40]-[46].

Hospital-based prevalence of invasive candidiasis

According to studies, clinical forms and countries, the prevalence of IC ranged from 0.14% to 5.5%. Candidemia prevalence varied widely across countries and even between studies in the same country (I^2 = 95%). Candidemia prevalence was somewhat higher in Nigeria, notably among newborns (5.5%) and immunosuppressed patients (5.2%) [36] [37], and much lower in Ghana [33] [34]. The pooled prevalence of clinical candidemia and non-candidemic IC in West Africa were 0.35% [95% CI 0.23; 0.47] and 0.32% [95% CI 0.00; 2.03], respectively. Figure 2 represents the meta-analysis data of IC prevalence.

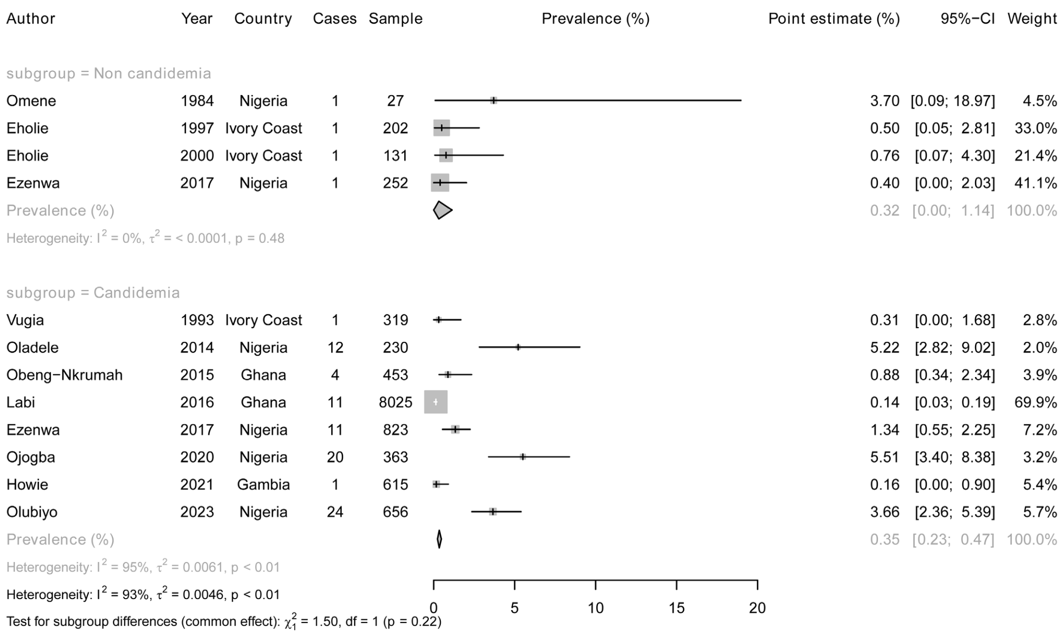

Figure 2. Forest plot of prevalence of candidemia and non-candidemic invasive candidiasis in west Africa.

Population-based estimation of invasive candidiasis incidence

Based on incidence data from international studies and the prevalence of risk factors in each country, the authors have estimated the nationwide incidence of the two most common clinical forms of IC. The annual incidence rate of candidemia was estimated at 6/100,000 inhabitants in Nigeria [43] and 5/100,000 inhabitants in the other countries [40]-[42] [44]-[46]. The pooled incidence of candidemia was 5.55/100,000 (95% CI 5.46; 5.64). The annual incidence rate of *Candida* peritonitis was estimated at 0.75 per 100000 inhabitants in all the countries except for Nigeria (1.5 per 100,000) and the pooled incidence at 1.15 (CI 95% 1.11 - 1.19) [40]-[46]. The meta-analysis data are summarized in **Figure 3**.

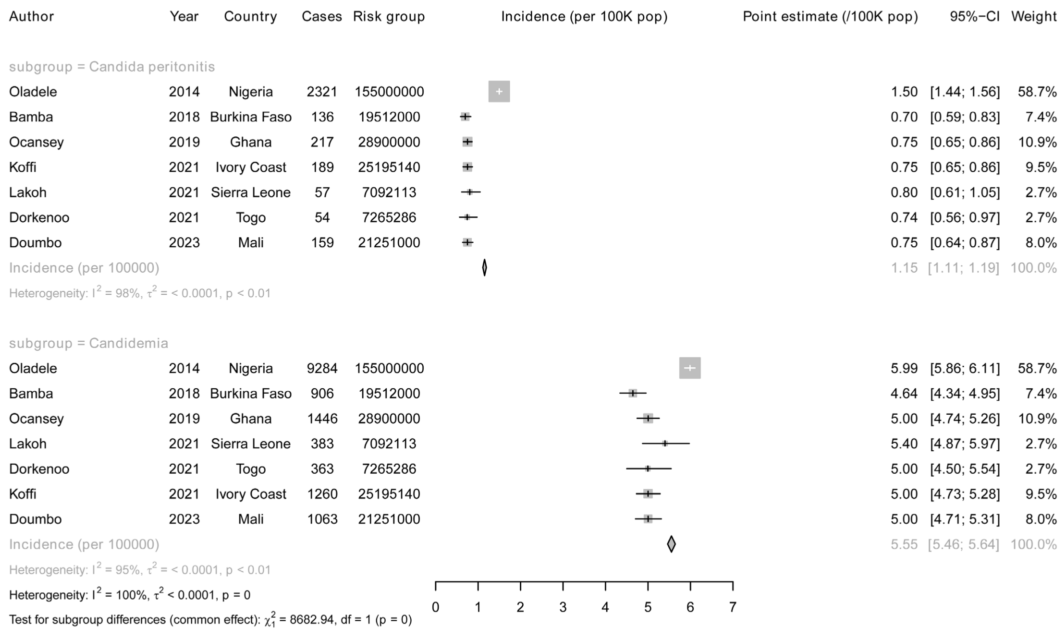

Figure 3. Forest plot of estimated incidence of candidemia and *Candida* peritonitis in west Africa.

3.3. Clinical Manifestations

Hospital-based studies reported 96 IC cases with candidemia as the most common clinical manifestation (90/96) [24]-[26] [29] [32]-[37] [39]. The second most frequent form was *Candida* meningitis, accounting for four cases, one of which with candidemia [27] [30] [31] [35]. Other clinical forms observed included *Candida* peritonitis (1.56%) [26] and *Candida* osteomyelitis (1.56%) [26] [36]. Clinical cases of invasives candidiasis in west Africa are summarized in **Table 1**.

3.4. Risk Factors of Invasive Candidiasis in West Africa

The majority of IC cases were reported among newborns and infants under five-years-old (70/96) [26] [32] [34]-[36] [38] [39]. The other cases were retrieved from immunocompromised patients, including cancer, human immunodeficiency virus (HIV) and pancytopenia [24] [29] [33] [37]. Low gestational age, exposure to broad-spectrum antibiotics and invasive procedures were common predisposing factor of IC in neonatal intensive care unit [35].

Table 1. Prevalence of invasive candidiasis in West African hospitals.

Author and year	Country	Study type	Population	Clinical form	Sample	Speciation	*Candida* species	Sample size	Number of cases	Prevalence rate	Mortality	ATF testing	Treatment
Eholie *et al.*, 1997 [31]	Cote d'Ivoire	Cross-sectional	Inpatient with HIV (adults)	Disseminated candidiasis (Candidemia+ *Candida* meningitis)	Blood and CSF	-	*Candida tropicalis*	202	1	0.005%	100%	-	AMB
Eholie *et al.*, 2000 [30]	Cote d'Ivoire	Cross-sectional	Non-viral lymphocytes meningitis (adult)	*Candida* meningitis	CSF	-	*C. albicans*	131	1	0.76%	-	-	-
Vugia *et al.*, 1993 [29]	Cote d'Ivoire	Cross-sectional study	HIV and non-HIV patients	Candidemia	Blood	Biochemical method	*C. lusitaniae*	319	1	0.31%	-	-	-
Howie *et al.*, 2021 [32]	Gambia	Cross-sectional	Chronically malnourished children with severe pneumonia	Candidemia	Blood	-	*Candida sp.*	615	1	0.16%	-	-	-
Labi *et al.*, 2016 [34]	Ghana	Cross-sectional	Neonatal patients	Candidemia	Blood	Morphological identification	*C. albicans*	8025	11	0.14%	-	-	-
Obeng-Nkrumah *et al.*, 2015 [33]	Ghana	Cross-sectional	Cancer (solid and haematological)	Candidemia	Blood	Morphological identification	*C. albicans*	453	4	0.88%	-	-	-
Ojogba *et al.*, 2020 [36]	Nigeria	Cross-sectional	Newborns with sepsis	Candidemia	Blood	ITS sequencing	*C. albicans* (11), *C. glabrata* (5), *C. tropicalis* (3), *C. parapsilosis* (1)	363	20	5.50%	-	BMD: All isolates were susceptible to FLU, VOR, and AMB B	-
Sanni *et al.*, 2023 [26]	Nigeria	Case report	Preterm newborn with sepsis	Candidemia	Blood	-	*C. parapsilosis*	-	1	-	0%	-	FLU and secondarily replaced by AMB B
Ezenwa *et al.*, 2017 [35]	Nigeria	Cross-sectional	Newborns in intensive care unit	Candidemia	Blood	Germ tube test	*Candida sp.*	823	11	1.30%	18%	-	FLU
				Candida meningitis	CSF	-	*Candida krusei*	252	1	0.40%	100%	-	FLU
Olubiyo *et al.*, 2023 [39]	Nigeria	Cross-sectional	Paediatric in-patients with severe sepsis	Candidemia	Blood	-	*Candida sp.*	656	24	3.66%	-	-	-
Ukekwe *et al.*, 2015 [28]	Nigeria	Case report	Gastric perforation (adult)	*Candida* gastric perforation	Gastric biopsy	-	*Candida sp.*		1	-	-	-	FLU
Sanya *et al.* 2007 [27]	Nigeria	Case report	Suspected immunocompromised (adult)	*Candida* meningitis	CSF	-	*C. albicans*	-	1	-	0%	-	FLU + NYS
Nwadike *et al.*, 2013 [24]	Nigeria	Case report	Immunocompromised (adult)	Candidemia	Blood	-	*C. albicans*	1	1	-	100%	-	FLU
Omene *et al.* 1984 [38]	Nigeria	Cross-sectional	Neonatal with osteomyelitis	*Candida* osteomyelitis	Articular fluid	-	*C. albicans*	27	1	3.70%	-	-	AMB
Oladele *et al.*, 2022 [25]	Nigeria	Case report	Sepsis in adult	Candidemia	Blood	VITEK	*Candida auris*	-	4	-	75%	VITEK 2: (50% of FLU resistance)	1 case treated with FLU and VOR 1 case treated with VOR
Oladele *et al.*, 2014 [37]	Nigeria	Cross-sectional	Immunosuppressed patients (cancer, diabetes, renal diseases, severe burns, severe head injury, HIV, sepsis, very low birth weight)	Candidemia	Blood	CHROMagar *Candida*, Germ tube test, API 20C AUX and/or ID 32C	*C. tropicalis* (7) *C. parapsilosis* (4) *C. albicans* (2)	230	12 (13 strains)	5.20%	91.7%	BMD: All isolates were susceptible to FLU	FLU

CSF: cerebrospinal fluid, BMD: broth microdilution, FLU: fluconazole, VOR: voriconazole, AMB: amphotericin B, NYS: nystatin.

3.5. Diagnostic and Therapeutic Management

Almost all IC cases (95/96) were diagnosed by microbiologic cultures. Histopathologic analysis contributed to the diagnosis of one case of gastric perforation [28]. Non-culture diagnostic test was not used. *Candida* species identification technique was described in seven studies, and phenotypic technique was the most used. Morphological identification was used in two studies from Ghana [33] [34], whereas biochemical tests (API 20C AUX, ID 32C) were used in one study from Cote d'Ivoire [29] and two studies from Nigeria [37]. VITEK-2 was used in one Nigerian study and allowed the identification of *Candida auris* species [25]. The molecular identification (ITS sequencing) was performed in only one study [36]. The different laboratory techniques allowed the speciation of 61.86% (60/97) *Candida* isolates belonging to 7 species (*C. albicans*, *C. tropicalis*, *C. parapsilosis*, *N. glabratus*, *C. auris*, *P. kudriavzevii*, and *C. lusitaniae*) [24]-[26] [29] [30] [33]-[38].

Among fully identified isolates, *C. albicans* was the most common species 32.98% (32/97), followed by *C. tropicalis* (11.34%), *C. parapsilosis* (6.19%), and *N. glabratus,* (5.15%). *C. auris* was diagnosed in four patients while only one case of each of *P. kudriavzevii,* and *C. lusitaniae* were reported.

3.6. Antifungal Susceptibility Profile and Prognostic Data

Antifungal susceptibility was tested in three studies. Clinical and Laboratory Standard Institute (CLSI) broth microdilution method was used in two studies, and no resistance was noticed against fluconazole, voriconazole and amphotericin B [36] [37]. In another study, four *C. auris* isolates were tested using VITEK-2 system and found that two strains were fluconazole-resistant with confirmed genetic mutation (ERG11:Y132F) [25]. However, all *C. auris* isolates were susceptible to the other tested antifungals (voriconazole, amphotericin B, caspofungin, micafungin and anidulafungin) [25].

Fluconazole was the main antifungal drug used to manage IC in West Africa (90.63%, 29/32) [24] [26]-[28] [35] [37]. Amphotericin B was the second most common antifungal and it was used in one case of *C. albicans* osteomyelitis, and two cases of *Candida* meningitis [26] [31] [38]. Voriconazole was used in one study to treat two cases of *C. auris* candidemia [25].

Eight studies reported IC treatment outcome, and overall mortality rate was 57.58% [24]-[28] [31] [35] [37]. Candidemia mortality was 58.62% while the other clinical forms of IC mortality was 50%.

3.7. Publication Bias

The funnel plots of the studies included in the meta-analysis of population-based incidence and hospital-based prevalence show some asymmetry, suggesting the presence of publication bias (**Appendix**: **Figure A1** and **Figure A2**).

4. Discussion

The aim of this review is to assess the burden and therapeutic management of IC in the West African region. Invasive candidiasis is a potentially fatal infection that is on the rise in developed countries due to the increased at-risk population [47] [48]. However, data related to this disease are still lacking in low- and middle-income worlds such as West Africa. The findings of this review could potentially fill this gap and contribute to a better understanding of IC in this West African region, thereby stimulating further research and data production.

This review showed that IC data in West Africa are scarce, as highlighted by the low number of countries reporting hospital cases. This gap would indicate the need for more awareness of medical staff on the burden of IFIs in this region. To mitigate this gap, West African countries have used the deterministic model developed by the Leading International Fungal Education (LIFE) program, to estimate the nationwide burden of severe fungal infections including IC [47]. Thus, estimated data on the annual incidence of candidemia and *Candida* peritonitis have already been produced in Burkina Faso, Cote d'Ivoire, Ghana, Mali, Nigeria, Sierra Leone, and Togo [40]-[45] [49]. The estimated data generated through this methodological approach showed that many IC cases remained undiagnosed. Moreover, in countries where no clinical case of IC has not yet been reported, this is more likely due to undiagnosed IC cases rather than an actual absence of this infection. Undiagnosed IC cases could have significant implications for patients and healthcare system including inappropriate and excessive use of broad-spectrum antibiotic contributing to antimicrobial resistance. Efforts must be pursued to stimulate data production in the remaining countries and to raise awareness of IC in the routine practice of physicians and microbiologists. Indeed, a survey in Nigeria revealed that the awareness of IFIs among resident doctors was deficient and urgently needed [18]. Studies of this kind undoubtedly help raise physicians' awareness of these pathologies and improve the reporting of IC cases in the country. This example should motivate other countries in the region to enhance awareness and research on IFIs.

In West African hospitals, the overall prevalence of IC was low 0.35% (95% CI 0.23; 0.47) with candidemia being the most common clinical manifestation. This prevalence reported in this review may be underestimated because it includes only culture-proven cases of IC. Indeed, the microscopic cultures (gold standard diagnostic tests) have low sensitivity about 50% [50]. The use of non-culture diagnostic tests such as mannan antigen, anti-mannan antibodies, *C. albicans* germ tube antibody, 1,3-β-D-glucan, T2*Candida* panel or PCR, could improve the diagnosis of IC notably in culture-negative samples [51]-[53]. However, these innovative diagnostic tests remain inaccessible to resource-limited laboratories due to their high cost.

Nonetheless, the clinical manifestations of IC documented in this review are consistent with previously studies from USA, Europe and Asia, where candidemia is identified as the predominant form of IC [1] [8] [13] [54] [55]. Many factor could contribute to the prevalence of clinical form of IC including the population underlying medical condition, invasive medical procedure and genetic predisposition to the infection [56]-[58]. Historically, factors associated with the higher risk for IC include long-term stays in the critical care unit settings, immunosuppression, diabetes mellitus, renal failure, gastrointestinal perforation/surgery, central venous catheter, broad-spectrum antibiotic, total parenteral nutrition prematurity, deficient birth weight, and pancreatitis [1] [4] [59]-[62]. In our review, only one study from Nigeria found that the occurrence of IC infection was associated with low birth weight (<1500 g), exposure to invasive procedures, and broad-spectrum antibiotic use [35]. Indeed, future studies should investigate potential risk factors specific to the sub-Saharan Africa environment, including, malnutrition, HIV infection, poverty, personal hygiene, socio-economic status, and healthcare access [13] [63].

The available data on IC causative agents shows that *C. albicans* is the most common species in West Africa. This finding aligns with the global trend across Africa, where *C. albicans* remains the leading cause of IC. However, there is a rising prevalence of non-*albicans Candida* species, such as *Candida parapsilosis* and *C. auris*, particularly in South Africa [13]. In the context of emergence of non-*albicans Candida* species including the multidrug resistant *C. auris*, *Candida* identification at the species-level become crucial for the initiation of adequate therapy and ensuring epidemiological surveillance of the infection.

Antifungal susceptibility was tested in only three studies using broth microdilution and VITEK-2 tests. Ojogba *et al.* tested 20 *Candida* isolates (*C. albicans*, *C. tropicalis*, *C. parapsilosis*, and *C. glabrata*) for susceptibility to fluconazole, voriconazole, and amphotericin B, reporting that all isolates were susceptible to these antifungal agents. Similarly, Oladele *et al.* found no drug resistance among 13 *Candida* strains (*C. albicans*, *C. tropicalis*, and *C. parapsilosis*) tested against fluconazole (MIC < 8 μg/ml) [36] [37]. In another study, Oladele *et al.* found fluconazole resistance in 50% (2/4) of *Candida auris* isolates (MIC ≥ 32 μg/ml), but no resistance was found with amphotericin B or echinocandins. Overall, fluconazole resistance remains relatively low as 5.55%, which is reassuring given the global rise in antifungal resistance among *Candida* isolates [23] [64].

In this review, six studies provided data on antifungal therapy encompassing a total of 30 IC cases. Fluconazole was the most common antifungal drug used (90.63%, 29/32) in IC management [24] [25] [28] [35] [37] [38]. Despite the administration of susceptible drugs, IC global mortality remains high (57.58%), especially among immunocompromised patients (91.7%) [37]. This paradox highlights that the prognosis of IC depends not only on effective antifungal drugs but also on early diagnosis and treatment, infection source control, and management of risk factors and underlying conditions [65]-[67].

The meta-analysis of IC prevalence in West Africa shows substantial heterogeneity among included studies (I^2 = 93%), warranting caution when generalizing the pooled prevalence. This heterogeneity may stem for differences in study populations and methodologies. The prevalence of IC varied widely across countries and studies, depending on factors such as the population's underlying condition, the performance of laboratory diagnostic methods, and the quality of the healthcare system [56]. This variability highlights the urgent need for a larger, multi-country studies using standardized methods to accurately assess the true burden of invasive candidiasis (IC) in West Africa and to guide the development of more effective global strategies.

The major limitation of our review was the small number of citations of included studies. Data on IC were available from only eight out of 16 countries, with hospital-based data from just four. This scarcity likely underrepresents the true burden of the disease in the population, complicating efforts to reliably extrapolate findings across West Africa. Additionally, *Candida* species distribution may vary, as the laboratory methods for speciation differed across studies and often had low discriminatory power. Finally, the hospital-based data focused on culture-confirmed IC, without using immunological, molecular, or proteomic diagnostic methods. This reliance on culture methods, which have a detection rate of only 50%, likely underestimates the true burden of IC. [59].

Despite these limitations, this review provided an overview of the current epidemiology of IC in West Africa and highlighted the necessity for field epidemiological studies to accurately assess its burden and recommend tailored control strategies suitable for the local context.

5. Conclusions

This review showed the scarcity of IC data in west Africa and above all the existence of undiagnosed IC cases. This study also showed the dire need for more IC data in the West African region. Finally this study showed the low awareness of medical personnel about the threat posed by IC.

In this context, it is crucial to develop innovative strategies that can bridge these gaps. This includes enhancing clinical laboratory capabilities and increasing awareness among microbiologists and physicians about the diagnosis and management of IC in West African hospitals. Additionally, the establishing national and regional surveillance systems for IC could provide regular data to better document the disease burden in hospital settings.

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Author Contributions

S.N.D., and H.R.V. conceived the original idea of the study, S.N.D. and I.WY. selected, extracted, and synthesised data, S.N.D and S.H.Z. performed the analysis, S.N.D wrote the first draft of the paper with the inputs of H.R.V., I.W.Y. and A.R. All authors reviewed the final version of the manuscript.

Conflicts of Interest

The authors have no conflict of interest.

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Appendix

Table A1. Search strategy on PubMed.

Search	Search terms
#1	"candidiasis, invasive" [MeSH Terms] OR ("candidiasis" [All Fields] AND "invasive" [All Fields]) OR "invasive candidiasis" [All Fields] OR ("invasive" [All Fields] AND "candidiasis" [All Fields]) OR (("invasibility" [All Fields] OR "invasible" [All Fields] OR "invasion" [All Fields] OR "invasions" [All Fields] OR "invasive" [All Fields] OR "invasively" [All Fields] OR "invasiveness" [All Fields] OR "invasives" [All Fields] OR "invasivity" [All Fields]) AND ("candidiasis" [MeSH Terms] OR "candidiasis" [All Fields] OR ("*candida*" [All Fields] AND "infection" [All Fields]) OR "*candida* infection" [All Fields])) OR ("candidemia" [MeSH Terms] OR "candidemia" [All Fields] OR "candidemias" [All Fields]) OR ("*candida*emias" [All Fields] OR "candidemia" [MeSH Terms] OR "candidemia" [All Fields] OR "*candida*emia" [All Fields]) OR (("disseminate" [All Fields] OR "disseminated" [All Fields] OR "disseminates" [All Fields] OR "disseminating" [All Fields] OR "dissemination" [All Fields] OR "disseminations" [All Fields] OR "disseminator" [All Fields] OR "disseminators" [All Fields]) AND ("candidiasis" [MeSH Terms] OR "candidiasis" [All Fields] OR "candidiases" [All Fields])) OR (("blood circulation" [MeSH Terms] OR ("blood" [All Fields] AND "circulation" [All Fields]) OR "blood circulation" [All Fields] OR "bloodstream" [All Fields] OR "bloodstreams" [All Fields]) AND ("candidiasis" [MeSH Terms] OR "candidiasis" [All Fields] OR "candidiases" [All Fields])) OR ("systemic candidiasis" [Supplementary Concept] OR "systemic candidiasis" [All Fields] OR "systemic candidiasis" [All Fields])
#2	(("abdominal cavity" [MeSH Terms] OR ("abdominal" [All Fields] AND "cavity" [All Fields]) OR "abdominal cavity" [All Fields] OR "intraabdominal" [All Fields] OR "intraabdominally" [All Fields]) AND ("candidiasis" [MeSH Terms] OR "candidiasis" [All Fields] OR "candidiases" [All Fields])) OR (("*candida*" [MeSH Terms] OR "*candida*" [All Fields] OR "*candida*e" [All Fields] OR "*candida*s" [All Fields]) AND ("peritoneally" [All Fields] OR "peritoneum" [MeSH Terms] OR "peritoneum" [All Fields] OR "peritoneal" [All Fields] OR "peritonism" [All Fields] OR "peritonitis" [MeSH Terms] OR "peritonitis" [All Fields])) OR (("*candida*" [MeSH Terms] OR "*candida*" [All Fields] OR "*candida*e" [All Fields] OR "*candida*s" [All Fields]) AND ("pancreas" [MeSH Terms] OR "pancreas" [All Fields] OR "pancreatic" [All Fields] OR "pancreatitides" [All Fields] OR "pancreatitis" [MeSH Terms] OR "pancreatitis" [All Fields])) OR (("spleen" [MeSH Terms] OR "spleen" [All Fields] OR "spleens" [All Fields] OR "spleen s" [All Fields]) AND ("candidiasis" [MeSH Terms] OR "candidiasis" [All Fields] OR "candidiases" [All Fields])) OR (("liver" [MeSH Terms] OR "liver" [All Fields] OR "livers" [All Fields] OR "liver s" [All Fields]) AND ("candidiasis" [MeSH Terms] OR "candidiasis" [All Fields] OR "candidiases" [All Fields])) OR (("*candida*" [MeSH Terms] OR "*candida*" [All Fields] OR "*candida*e" [All Fields] OR "*candida*s" [All Fields]) AND ("arthritis" [MeSH Terms] OR "arthritis" [All Fields] OR "arthritides" [All Fields] OR "polyarthritides" [All Fields])) OR (("*candida*" [MeSH Terms] OR "*candida*" [All Fields] OR "*candida*e" [All Fields] OR "*candida*s" [All Fields]) AND ("discitis" [MeSH Terms] OR "discitis" [All Fields] OR "spondylodiscitis" [All Fields])) OR (("*candida*" [MeSH Terms] OR "*candida*" [All Fields] OR "*candida*e" [All Fields] OR "*candida*s" [All Fields]) AND ("osteomyelities" [All Fields] OR "osteomyelitis" [MeSH Terms] OR "osteomyelitis" [All Fields] OR "osteomyelitides" [All Fields])) OR (("*candida*" [MeSH Terms] OR "*candida*" [All Fields] OR "*candida*e" [All Fields] OR "*candida*s" [All Fields]) AND ("meningeal" [All Fields] OR "meninges" [MeSH Terms] OR "meninges" [All Fields] OR "meninge" [All Fields] OR "meningism" [MeSH Terms] OR "meningism" [All Fields] OR "meningisms" [All Fields] OR "meningitis" [MeSH Terms] OR "meningitis" [All Fields] OR "meningitides" [All Fields])) OR (("*candida*" [MeSH Terms] OR "*candida*" [All Fields] OR "*candida*e" [All Fields] OR "*candida*s" [All Fields]) AND ("encephalities" [All Fields] OR "encephalitis" [MeSH Terms] OR "encephalitis" [All Fields])) OR (("*candida*" [MeSH Terms] OR "*candida*" [All Fields] OR "*candida*e" [All Fields] OR "*candida*s" [All Fields]) AND ("endophthalmitis" [MeSH Terms] OR "endophthalmitis" [All Fields] OR "endophthalmitides" [All Fields])) OR

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#2	((“*candida*” [MeSH Terms] OR “*candida*” [All Fields] OR “*candida*e” [All Fields] OR “*candida*s” [All Fields]) AND (“chorioretinal” [All Fields] OR “chorioretinitis” [MeSH Terms] OR “chorioretinitis” [All Fields] OR “chorioretinitides” [All Fields])) OR ((“*candida*” [MeSH Terms] OR “*candida*” [All Fields] OR “*candida*e” [All Fields] OR “*candida*s” [All Fields]) AND (“endocarditis” [MeSH Terms] OR “endocarditis” [All Fields] OR “endocarditides” [All Fields])) OR ((“*candida*” [MeSH Terms] OR “*candida*” [All Fields] OR “*candida*e” [All Fields] OR “*candida*s” [All Fields]) AND (“pericardic” [All Fields] OR “pericarditis” [MeSH Terms] OR “pericarditis” [All Fields])) OR ((“*candida*” [MeSH Terms] OR “*candida*” [All Fields] OR “*candida*e” [All Fields] OR “*candida*s” [All Fields]) AND (“pneumonia” [MeSH Terms] OR “pneumonia” [All Fields] OR “pneumonias” [All Fields] OR “pneumoniae” [All Fields] OR “pneumoniae s” [All Fields])) OR ((“*candida*” [MeSH Terms] OR “*candida*” [All Fields] OR “*candida*e” [All Fields] OR “*candida*s” [All Fields]) AND (“pleurisy” [MeSH Terms] OR “pleurisy” [All Fields] OR “pleuritis” [All Fields])) OR ((“*candida*” [MeSH Terms] OR “*candida*” [All Fields] OR “*candida*e” [All Fields] OR “*candida*s” [All Fields]) AND (“pyelonephritis” [MeSH Terms] OR “pyelonephritis” [All Fields] OR “pyelonephritides” [All Fields])) OR ((“renal” [All Fields] OR “renals” [All Fields]) AND (“candidiasis” [MeSH Terms] OR “candidiasis” [All Fields] OR “candidiases” [All Fields]))
#3	benin [Title/Abstract] OR (burkina faso [Title/Abstract]) OR (cabo verde [Title/Abstract]) OR (cote d'ivoire [Title/Abstract]) OR gambia [Title/Abstract] OR ghana [Title/Abstract] OR guinea [Title/Abstract] OR (guinea bissau [Title/Abstract]) OR liberia [Title/Abstract] OR mali [Title/Abstract] OR mauritania [Title/Abstract] OR niger [Title/Abstract] OR nigeria [Title/Abstract] OR senegal [Title/Abstract] OR (sierra leone [Title/Abstract]) OR togo [Title/Abstract]
#4	(#1 OR #2) AND #3

Date: 09 June 2024: 316 citations found

Table A2. Search strategy on Scopus.

Search	Search terms
#1	ALL (“invasive AND candidiasis” OR “invasive AND *candida* AND infection” OR candidemia OR *candida*emia OR “disseminated AND candidiasis” OR “bloodstream AND candidiasis” OR “systemic AND candidiasis”)
#2	ALL (“intraabdominal candidiasis” OR “*candida* peritonitis” OR “*candida* pancreatitis” OR “spleen candidiasis” OR “liver candidiasis” OR “*candida* arthritis” OR “*candida* spondylodiscitis” OR “*candida* osteomyelitis” OR “*candida* meningitis” OR “*candida* encephalitis” OR “*candida* endophthalmitis” OR “*candida* chorioretinitis” OR “*candida* endocarditis” OR “*candida* pericarditis” OR “*candida* pneumonia” OR “*candida* pleuritis” OR “*candida* pyelonephritis” OR “renal candidiasis”)
#3	TITLE-ABS-KEY (benin OR (burkina faso) OR (cabo 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)
#4	(#1 OR #2) AND #3

Date 09 June 2024: 425 citations found

Table A3. Search strategy on Embase.

Search	Search terms
#1	'invasive candidiasis'/exp OR 'invasive candidiasis' OR (invasive AND ('candidiasis'/exp OR candidiasis)) OR 'invasive *candida* infection' OR (invasive AND ('*candida*'/exp OR *candida*) AND ('infection'/exp OR infection)) OR 'candidemia'/exp OR candidemia OR '*candida*emia'/exp OR *candida*emia OR 'disseminated candidiasis'/exp OR 'disseminated candidiasis' OR (disseminated AND ('candidiasis'/exp OR candidiasis)) OR 'bloodstream candidiasis' OR (bloodstream AND ('candidiasis'/exp OR candidiasis)) OR 'systemic candidiasis'/exp OR 'systemic candidiasis' OR (systemic AND ('candidiasis'/exp OR candidiasis))
#2	'intraabdominal candidiasis'/exp OR 'intraabdominal candidiasis' OR '*candida* peritonitis'/exp OR '*candida* peritonitis' OR '*candida* pancreatitis' OR 'spleen candidiasis' OR 'liver candidiasis' OR '*candida* arthritis'/exp OR '*candida* arthritis' OR '*candida* spondylodiscitis' OR '*candida* osteomyelitis' OR '*candida* meningitis'/exp OR '*candida* meningitis' OR '*candida* encephalitis' OR '*candida* endophthalmitis'/exp OR '*candida* endophthalmitis' OR '*candida* chorioretinitis' OR '*candida* endocarditis'/exp OR '*candida* endocarditis' OR '*candida* pericarditis' OR '*candida* pneumonia'/exp OR '*candida* pneumonia' OR '*candida* pleuritis' OR '*candida* pyelonephritis' OR 'renal candidiasis'
#3	benin:ti,ab,kw OR 'burkina faso':ti,ab,kw OR 'cabo verde':ti,ab,kw OR 'cote d ivoire':ti,ab,kw OR gambia:ti,ab,kw OR ghana:ti,ab,kw OR guinea:ti,ab,kw OR 'guinea bissau':ti,ab,kw OR liberia:ti,ab,kw OR mali:ti,ab,kw OR mauritania:ti,ab,kw OR niger:ti,ab,kw OR nigeria:ti,ab,kw OR senegal:ti,ab,kw OR 'sierra leone':ti,ab,kw OR togo:ti,ab,kw
#4	(#1 OR #2) AND #3

Date 09 June 2024: 195 citations found

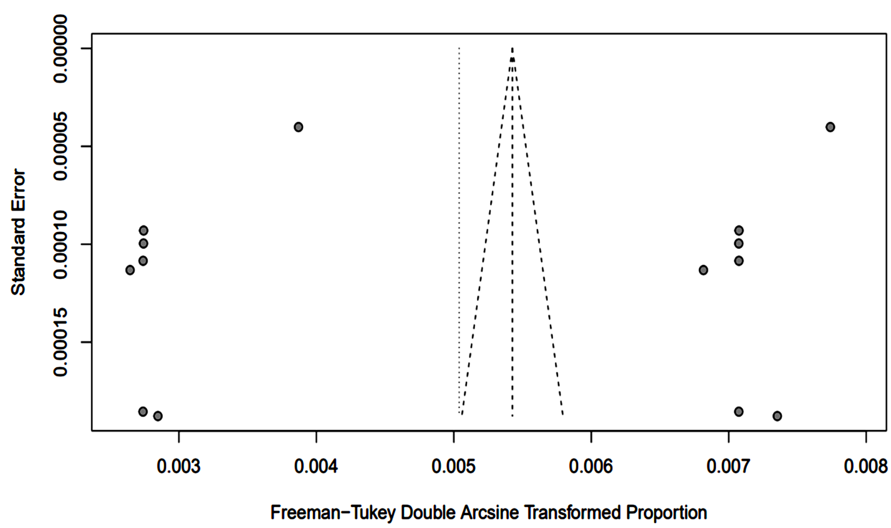

Figure A1. Funnel plot of studies included in the meta-analysis of estimated incidence of invasive candidiasis in West African region.

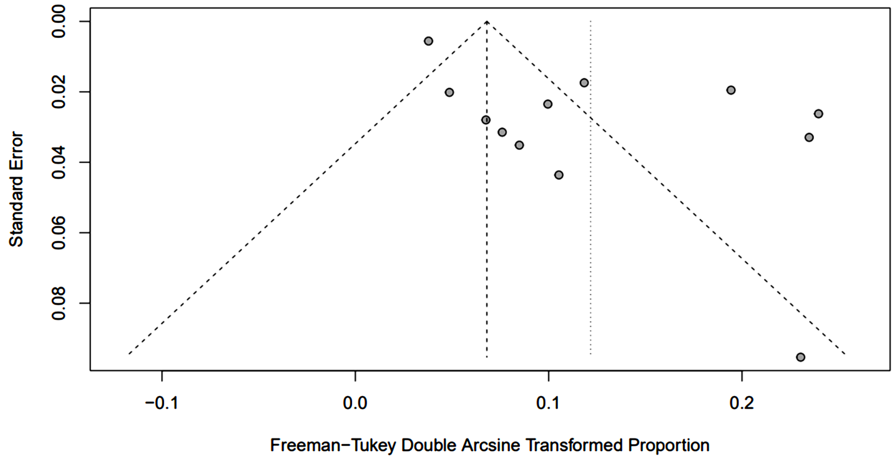

Figure A2. Funnel plot of studies included in the meta-analysis of invasive candidiasis prevalence in West African region.