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Epidemiology of Candida Spp. Infections and Antifungal Resistance in Morocco: Current Knowledge, Gaps, and Perspectives

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Abstract | **Original Research Article**

Background: Candida spp. infections represent an important cause of morbidity and mortality, particularly among hospitalized and critically ill patients. Although *Candida albicans* remains a major causative species, the increasing contribution of non-albicans Candida species and the emergence of antifungal resistance constitute growing clinical and public health concerns. In Morocco, epidemiological and antifungal susceptibility data remain limited and heterogeneous. ***Objective:*** This narrative review aimed to synthesize the available evidence on the epidemiology of *Candida* spp. infections in Morocco, with particular emphasis on species distribution, antifungal susceptibility and resistance patterns, major knowledge gaps, and priorities for future surveillance. ***Methods:*** A literature search was conducted in PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar, complemented by manual screening of reference lists. Publications mainly covering the period from January 2005 to August 2026 were considered. Studies reporting data on *Candida* spp. infections, species distribution, antifungal susceptibility or resistance in Morocco were included. Because of substantial heterogeneity in study populations, clinical settings, identification methods, and susceptibility-testing procedures, the available evidence was analyzed descriptively. ***Results:*** The available Moroccan literature remains geographically and methodologically fragmented. *C. albicans* is frequently reported as the predominant species, while non-albicans Candida species, particularly *C. glabrata*, *C. parapsilosis*, and *C. tropicalis*, account for a substantial proportion of isolates in several clinical settings. Recent studies have also demonstrated greater species diversity when molecular identification methods are used. Reduced susceptibility or resistance to fluconazole and anidulafungin has been reported, including isolates displaying resistance to more than one antifungal class. However, the available data are insufficient to estimate national resistance rates. The emergence of *Candida auris* in several African countries further emphasizes the need for improved diagnostic and surveillance capacity, although published data confirming its presence in Morocco remain lacking. ***Conclusion:*** Current evidence indicates that *Candida* infections and antifungal resistance represent an emerging surveillance challenge in Morocco, but the national burden remains poorly characterized. Multicenter prospective surveillance using standardized species identification and antifungal susceptibility-testing methods, combined with clinical and molecular data, is urgently needed. Strengthening *C. auris* detection and antifungal stewardship should be integrated into a coordinated national strategy to improve the prevention and management of Candida infections in Morocco.

Keywords: *Candida* spp., antifungal resistance; Morocco, epidemiology.

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INTRODUCTION

Candida spp. infections represent an important cause of fungal infections in humans and may manifest in various clinical forms, ranging from superficial infections to potentially fatal invasive infections. Candidemia and other invasive candidiasis mainly occur in patients with risk factors such as prolonged hospitalization, intensive care unit stay, use of intravascular catheters, exposure to broad-spectrum antibiotics, surgical procedures, and immunosuppression. Despite the increasing importance of these infections, their true epidemiological burden remains difficult to determine in many countries because diagnostic capacities and surveillance systems are still insufficient [1,2].

Candida albicans generally remains the species most frequently isolated from Candida infections. However, non-albicans species, particularly C. glabrata,

C. parapsilosis, C. tropicalis, and C. krusei, play an important role in invasive infections. This situation is of particular clinical importance because antifungal susceptibility differs among species and resistant phenotypes may emerge. Surveillance of species distribution is therefore an essential component of candidiasis management and of adapting therapeutic strategies [3,4].

Antifungal resistance is currently one of the major challenges associated with Candida infections. Azoles, particularly fluconazole, have long played a major role in the treatment of candidiasis. However, repeated exposure to antifungal agents may promote the selection of less susceptible or resistant strains. Resistance may also involve echinocandins, which constitute a major therapeutic class for the management of invasive candidiasis. The limited number of available antifungal classes, together with the emergence of resistant or multidrug-resistant strains, restricts therapeutic options and represents a growing public health concern [4].

In Africa, assessing the true incidence of candidiasis and antifungal resistance remains particularly difficult. Available data are often fragmented and derived from single-center studies, while access to modern species-identification and antifungal susceptibility-testing methods varies considerably between countries and healthcare facilities. This situation may lead to underestimation of the true burden of Candida infections and limit the ability to detect the emergence of antifungal resistance at an early stage [4,5].

This issue is particularly relevant in Morocco. A study estimating the burden of serious fungal infections in the country highlighted the scarcity of available epidemiological data. The authors estimated the incidence of candidemia at approximately 5 cases per 100,000 inhabitants per year, corresponding to approximately 1,830 cases annually. However, they emphasized that these figures were estimates and that confirmation would require methodologically robust national epidemiological studies [1]. The absence of representative surveillance data therefore constitutes an important limitation for assessing the dynamics of Candida infections and the evolution of antifungal resistance in Morocco.

Data from different Moroccan healthcare facilities also suggest variable Candida species distributions according to clinical and geographic context. In Fez, a retrospective study conducted at Hassan II University Hospital between January 2017 and July 2022 identified 42 cases of candidemia among 145 blood cultures analyzed. Non-albicans species accounted for 64.2% of the reported isolates, including C. glabrata, C. tropicalis, C. parapsilosis, C. krusei, and C. lusitaniae. In this series, reported susceptibility rates were 89% for amphotericin B and 70% for fluconazole [6].

More recent data from northern Morocco provide additional information on species diversity and antifungal susceptibility. In a study conducted in Tetouan on a collection of 93 clinical isolates from four healthcare facilities, C. albicans accounted for 64.52% of isolates, followed by C. glabrata (15.05%), C. parapsilosis (6.45%), and C. tropicalis (4.30%). Nine Candida species were identified, including C. metapsilosis, reported for the first time in Morocco in this study [3].

The Tetouan study also assessed susceptibility to fluconazole and anidulafungin according to EUCAST methodology. Two C. albicans isolates and one C. glabrata isolate showed elevated minimum inhibitory concentrations to fluconazole. Isolates resistant to anidulafungin were also identified among C. albicans, C. tropicalis, and C. krusei. The two C. krusei isolates additionally showed intrinsic resistance to fluconazole, corresponding to resistance to two antifungal classes in this series [3].

Available Moroccan data therefore show some heterogeneity in the distribution of Candida species. This variability may be related to differences in the populations studied, types of infection, hospital departments involved, identification methods used, and antifungal susceptibility-testing protocols. A study conducted in Rabat notably demonstrated the value of comparing different methods for determining the susceptibility of Candida isolates to antifungal agents, highlighting the importance of standardized methods for obtaining comparable data across healthcare facilities [7].

Furthermore, the international emergence of Candida auris reinforces the importance of structured mycological surveillance. This species is of particular concern because of its ability to cause invasive infections, persist in the hospital environment, and exhibit resistance to several antifungal classes. Early detection of C. auris requires sufficiently accurate identification methods, as some conventional methods may be inadequate for correctly differentiating certain closely related species [3,5].

In Morocco, currently available data therefore remain insufficient to establish a precise national estimate of the prevalence of different Candida species and their resistance profiles. Published studies have mainly been conducted in hospital centers or individual laboratories and have used different populations, diagnostic methods, and susceptibility criteria. This heterogeneity limits direct comparison of results and highlights the need to develop more structured epidemiological and antifungal surveillance at the national level [1,3].

The objective of this review is therefore to analyze available data on the epidemiology of Candida

spp. infections in Morocco, examine the distribution of the main species involved, and assess the antifungal susceptibility and resistance profiles reported in Moroccan studies. This review also aims to highlight the main gaps in current knowledge, discuss the emergence of non-albicans species, particularly C. auris, and identify the perspectives needed to strengthen mycological surveillance and efforts to control antifungal resistance in Morocco.

2. METHODS

2.1. Review type

This study was designed as a literature review focusing on the epidemiology of Candida spp. infections and antifungal resistance in Morocco. Particular attention was paid to Candida species distribution, the different types of infection, antifungal susceptibility profiles, resistance mechanisms, and the emergence of non-albicans species, particularly Candida auris.

The literature search was structured according to principles of transparency recommended for literature reviews and was based on a predefined search strategy.

2.2. Bibliographic sources

The literature search was conducted in the main biomedical and scientific databases, including PubMed/MEDLINE, Scopus, and Web of Science. An additional search was performed in Google Scholar to identify potentially relevant publications not indexed in the main databases.

The reference lists of selected articles and relevant reviews were also manually examined to identify additional publications that might meet the inclusion criteria.

2.3. Search strategy

The search used different combinations of terms related to Candida, fungal infections, antifungal resistance, and Morocco. The main search terms included:

Candida, Candida albicans, non-albicans Candida, candidemia, candidiasis, invasive candidiasis, antifungal resistance, antifungal susceptibility, fluconazole, echinocandins, amphotericin B, Candida auris, and Morocco.

The terms were combined using the Boolean operators AND OR. A main search equation that could be used in PubMed is:

("Candida" OR "Candida albicans" OR "non-albicans Candida" OR candidiasis OR candidemia) AND (Morocco OR Moroccan) AND ("antifungal resistance" OR "antifungal susceptibility" OR fluconazole OR echinocandin OR amphotericin B)

Additional searches were performed using specific terms such as:

("Candida auris" AND Morocco) and (candidemia AND Morocco) to identify publications addressing specific issues.

2.4. Search period

The literature search mainly covered publications published between January 2005 and August 2026.

This period was selected to allow analysis of the evolution of Moroccan epidemiological data over a sufficiently long period, while giving particular attention to recent publications concerning antifungal resistance and the emergence of new species.

Publications published before 2005 were considered when they were of historical interest or provided particularly relevant information for understanding the epidemiology of candidiasis in Morocco.

2.5. Inclusion criteria

Publications meeting the following criteria were considered eligible:

- Studies conducted in Morocco or reporting specific data concerning the Moroccan population;
- Studies addressing infections caused by Candida spp.;
- Studies assessing the epidemiology, species distribution, or clinical characteristics of Candida infections;
- Studies evaluating antifungal susceptibility or resistance;
- Studies addressing microbiological identification of Candida species when they provided relevant epidemiological data;
- Systematic reviews, meta-analyses, and international recommendations used to contextualize Moroccan data;
- Publications available in French or English.

2.6. Exclusion criteria

The following were excluded:

- Publications not concerning Candida spp.;
- Articles that did not provide data relevant to the objective of the review;
- Duplicates identified in multiple databases;
- Publications whose scientific content could not be adequately verified;
- Experimental studies providing no data directly applicable to the epidemiology or resistance of Candida species in humans.

2.7. Publication selection

Reference selection was performed in several stages. First, the titles and abstracts of identified publications were screened to eliminate clearly irrelevant references. Second, the full texts of potentially eligible articles were assessed.

For each selected publication, the following information was extracted: year of publication, study location, study design, study period, study population, number of patients or isolates, type of infection, Candida species identified, identification methods, antifungal agents tested, method used to determine antifungal susceptibility, and main findings regarding resistance.

2.8. Data analysis

Given the heterogeneity of Moroccan studies in terms of population, clinical setting, microbiological methods, and antifungal susceptibility interpretation criteria, the results were analyzed descriptively.

Data were grouped according to several domains:

- Geographic distribution of studies in Morocco;
- Type of Candida infection;
- Species distribution;
- Antifungal susceptibility and resistance profiles;
- Methods used for species identification and antifungal susceptibility testing;
- Factors associated with resistance;
- Available data concerning emerging species, particularly Candida auris.

Moroccan data were distinguished from data originating from other African countries and from the international literature in order to avoid extrapolating results to the Moroccan population as a whole.

2.9. Presentation of results

The results of the literature search are presented in summary tables allowing comparison of the main Moroccan studies according to their location, population, species identified, and antifungal susceptibility profiles.

Particular attention will be paid to differences observed between studies and to methodological limitations that may explain variability in the results.

3. RESULTS: EPIDEMIOLOGY OF CANDIDA SPP. INFECTIONS IN MOROCCO

3.1. Availability of epidemiological data

Data concerning the epidemiology of *Candida spp.* infections in Morocco remain limited and are characterized by substantial geographic and methodological heterogeneity. Available publications mainly originate from studies conducted in hospital centers or university laboratories, with variable populations, specimen types, and microbiological methods. A national estimate published in 2022 assessed the incidence of candidemia at approximately 5 cases per 100,000 inhabitants per year; however, the authors emphasized that this estimate was based on limited data and should be confirmed by robust national epidemiological studies [1].

One of the main difficulties in assessing the burden of candidiasis in Morocco is therefore the absence of a standardized national system for continuously collecting data on isolated species, types of infection, and antifungal susceptibility. This situation limits the ability to establish reliable national trends and to directly compare results obtained in different regions of the country [1,2].

3.2. Distribution of Candida species

Available Moroccan studies show that *C. albicans* remains a frequently isolated species, but that non-albicans species account for a substantial proportion of isolates in several clinical settings.

A recent study conducted in the Tetouan region represents one of the most detailed Moroccan series available to date. Between March 2021 and February 2022, 93 clinical isolates from four laboratories were analyzed. Molecular identification revealed nine different species. *C. albicans* was the predominant species, with 60 isolates (64.52%), followed by *C. glabrata* with 14 isolates (15.05%), *C. parapsilosis* with 6 isolates (6.45%), and *C. tropicalis* with 4 isolates (4.30%) [3].

The same study also identified *C. metapsilosis*, which, according to the authors, represented the first report of this species in Morocco [3]. This finding illustrates the importance of improving microbiological identification methods, particularly when conventional phenotypic methods may fail to correctly differentiate closely related species.

In Fez, a study focusing on candidemia diagnosed at Hassan II University Hospital also reported a substantial proportion of non-albicans species. The differences observed between this series and the Tetouan series indicate that species distribution may vary according to the hospital setting and the population studied [6].

Thus, although *C. albicans* remains the dominant species in several Moroccan series, the relatively high proportion of non-albicans species justifies regular monitoring of their distribution. Such surveillance is particularly important because the different species have different antifungal susceptibility profiles [3,6].

Table I: Main Moroccan studies reporting data on Candida spp.

Study	Region	Period	Data type	N	Main findings / susceptibility data
Ahaik *et al.,* [3]	Tetouan	2021–2022	Clinical isolates	93	C. albicans 64.52%; C. glabrata 15.05%; C. parapsilosis 6.45%; C. tropicalis 4.30%; fluconazole and anidulafungin
Lemhouer *et al.,* [6]	Fez	2017–2022	Candidemia	42	High proportion of non-albicans species; fluconazole and amphotericin B
Uwingabiye *et al.,* [7]	Rabat	2012	Candida isolates	38	Several Candida species; comparison of antifungal susceptibility-testing methods

3.3. Geographic and clinical variability

Comparison of the available studies suggests variability in Candida species distribution according to geographic region and clinical context. In Tetouan, *C. albicans* accounted for nearly two thirds of the isolates studied, while a substantial proportion of non-albicans species was also observed [3]. In Fez, the candidemias studied were likewise characterized by a predominance of non-albicans species [6].

This variability should nevertheless be interpreted with caution. Differences between studies may be related not only to genuine geographic variation, but also to the characteristics of the patients included, the hospital departments involved, specimen types, study periods, and identification techniques.

Direct comparison of species proportions between different Moroccan cities should therefore be avoided until multicenter studies using standardized protocols become available.

3.4. Importance of identification methods

Correct species identification is an essential component of epidemiological surveillance of Candida infections. Conventional methods used in some Moroccan laboratories rely mainly on phenotypic characteristics. However, these methods may have limitations in identifying certain closely related species [3].

In the Tetouan study, comparison between routine phenotypic methods and molecular approaches showed that molecular identification provided more accurate species characterization. The study identified nine species and detected *C. metapsilosis*, which had not previously been reported in Morocco [3].

These findings suggest that the true diversity of Candida species circulating in Morocco may be underestimated when the identification methods used are insufficiently discriminatory. Improving diagnostic capacity is therefore essential for obtaining more reliable epidemiological data.

3.5. Main epidemiological findings

- *C. albicans* remains a major species among isolates studied in Morocco [3,6].
- Non-albicans species account for a substantial proportion of infections reported in several series [3,6].
- *C. glabrata*, *C. parapsilosis*, and *C. tropicalis* are among the main non-albicans species identified [3].
- Less frequently reported species, such as *C. metapsilosis*, can be detected using more advanced identification methods [3].
- National data remain fragmented and mainly originate from single-center studies [1,3].
- The heterogeneity of diagnostic methods and study populations limits comparisons between Moroccan studies.

These findings support the establishment of multicenter and standardized epidemiological surveillance of candidiasis in Morocco, combining accurate species identification with regular determination of antifungal susceptibility.

3.6. Candidemia and invasive infections

Candidemia is one of the most severe forms of *Candida spp.* infection and represents an important indicator of the burden of invasive candidiasis. In Morocco, available data remain limited and mainly originate from hospital series. A retrospective study conducted at Hassan II University Hospital in Fez between January 2017 and July 2022 identified 42 positive blood cultures among 145 blood cultures analyzed. Most of the patients were hospitalized in intensive care, accounting for 69% of cases. Non-albicans species represented 64.2% of isolates, including *C. glabrata*, *C. tropicalis*, *C. parapsilosis*, *C. krusei*, and *C. lusitaniae*. In this series, reported susceptibility rates were 89% for amphotericin B and 70% for fluconazole [6].

These findings suggest that candidemia observed in some Moroccan healthcare facilities may be characterized by a substantial proportion of non-albicans species. However, data from Hassan II University Hospital in Fez cannot be considered representative of the entire country. Recruitment from a university hospital and the high proportion of patients admitted to intensive care may influence the observed species distribution [6].

Species distribution has particular clinical importance because of differences in antifungal

susceptibility. Accurate knowledge of the causative species is therefore essential for interpreting susceptibility results and adapting antifungal management [3,4].

At the national level, an estimate published in 2022 assessed the incidence of candidemia in Morocco at approximately 5 cases per 100,000 inhabitants per year, corresponding to approximately 1,830 cases annually. The authors nevertheless emphasized the estimated nature of this value and the need for more robust national epidemiological data [1]. These data should therefore be interpreted as an estimate of the potential burden rather than as a measurement derived from a comprehensive national surveillance system.

3.7. Summary of the epidemiology of Candida spp. infections in Morocco

Overall, the currently available data show that the epidemiology of *Candida spp.* infections in Morocco remains insufficiently documented. *C. albicans* remains a frequently isolated species, but non-albicans species also play an important role in several clinical settings [3,6].

The study conducted in Tetouan between March 2021 and February 2022 is one of the most detailed recent Moroccan series. Among the 93 clinical isolates obtained from four healthcare facilities, *C. albicans* represented 64.52% of isolates, followed by *C. glabrata* (15.05%), *C. parapsilosis* (6.45%), and *C. tropicalis* (4.30%). Nine species were identified overall. The use of molecular methods notably enabled the identification of *C. metapsilosis*, reported by the authors as the first identification of this species in Morocco [3].

In Fez, a substantial proportion of non-albicans species was also observed among candidemia cases diagnosed at Hassan II University Hospital, with *C. glabrata*, *C. tropicalis*, *C. parapsilosis*, *C. krusei*, and *C. lusitaniae* among the identified species [6]. These observations confirm the diversity of species involved in Candida infections in Morocco, while also showing that their distribution may vary according to the clinical context and study population.

These results should nevertheless be interpreted cautiously. The available studies differ in geographic location, population, specimen type, study period, and identification methods. The proportions observed in these series therefore cannot be directly extrapolated to the Moroccan population as a whole [1,3,6].

Thus, current data do not allow a precise national distribution of the different Candida species to be established. The development of multicenter studies using standardized identification methods is needed to improve characterization of the epidemiology of candidiasis in Morocco.

4. Antifungal Resistance among Candida spp. in Morocco

4.1. General data on antifungal susceptibility

Moroccan data concerning antifungal susceptibility of *Candida spp.* remain limited and are based on studies conducted in different clinical settings and using variable assessment methods. This heterogeneity complicates direct comparison of results and estimation of a national antifungal resistance rate [3,4,7].

The study conducted in Tetouan between March 2021 and February 2022 provides recent data on the susceptibility of 93 clinical isolates to fluconazole and anidulafungin. Testing was performed using a methodology based on EUCAST recommendations. Two *C. albicans* isolates and one *C. glabrata* isolate had elevated minimum inhibitory concentrations to fluconazole [3].

The same study identified isolates resistant to anidulafungin, including one *C. albicans*, one *C. tropicalis*, and two *C. krusei* isolates. The two *C. krusei* isolates also showed intrinsic resistance to fluconazole, corresponding to resistance to two antifungal classes in this series [3].

These findings constitute an important signal indicating the presence of resistance profiles in Morocco. However, the limited number of isolates studied and the localized nature of the study do not allow estimation of the national frequency of resistance. Rather, they highlight the need for broader and standardized microbiological surveillance [3,4].

4.2. Susceptibility and resistance to azoles

Azoles, particularly fluconazole, play an important role in the treatment of Candida infections. Monitoring susceptibility to this therapeutic class is therefore an essential component of antifungal resistance surveillance [4].

In the study conducted at Hassan II University Hospital in Fez, fluconazole susceptibility was 70% among isolates responsible for candidemia. This value should nevertheless be interpreted in the context of the high proportion of non-albicans species observed in this series [6].

The Tetouan study provides complementary data. The authors identified two *C. albicans* isolates and one *C. glabrata* isolate with elevated minimum inhibitory concentrations to fluconazole. These findings do not indicate generalized fluconazole resistance, but they demonstrate the presence of isolates with reduced susceptibility and justify regular surveillance [3].

The study conducted in Rabat by Uwingabiye *et al.,* also provided susceptibility data for 38 Candida isolates. The collection included 15 *C. albicans*, 13 *C.*

glabrata, 5 *C. tropicalis*, 4 *C. krusei*, and 1 *C. dubliniensis*. Agreement between the two antifungal susceptibility-testing methods used was 97.4% for fluconazole, 100% for amphotericin B, and 94.7% for voriconazole [7].

Comparison of these studies shows that susceptibility profiles may vary according to the populations and species studied. It would therefore be inappropriate to calculate a national average fluconazole resistance rate from these different series. Such an estimate would require multicenter studies using comparable populations and standardized methods [3,6,7].

4.3. Echinocandin resistance

Echinocandins represent a major therapeutic class in the management of invasive candidiasis. The emergence of resistance to these antifungal agents is of particular concern because of the limited number of therapeutic classes available for treating invasive infections [4,5].

In Morocco, the Tetouan study provides recent data concerning echinocandin susceptibility. Four isolates resistant to anidulafungin were identified: one *C. albicans*, one *C. tropicalis*, and two *C. krusei*. The two *C. krusei* isolates also showed intrinsic resistance to fluconazole, corresponding to resistance to two antifungal classes [3].

Although these observations are concerning, they do not allow estimation of the national prevalence of echinocandin resistance. Nevertheless, they emphasize the value of including echinocandins in antifungal susceptibility surveillance programs, particularly for species at increased risk of resistance [3,4].

Surveillance of echinocandin resistance should also be accompanied, whenever possible, by investigations aimed at identifying the molecular mechanisms involved. However, currently available Moroccan studies do not yet allow comprehensive characterization of these mechanisms among circulating isolates in Morocco.

4.4. Influence of antifungal susceptibility-testing methods on comparability of results

One of the major difficulties in interpreting Moroccan data lies in the diversity of methods used to determine antifungal susceptibility. This issue is particularly important when comparing results obtained in different laboratories or at different time points [7].

The study conducted by Uwingabiye *et al.,* in Rabat compared two agar diffusion methods using Neo-Sensitabs® tablets and Bio-Rad® disks. The authors observed very good agreement between the two methods for amphotericin B, fluconazole, and voriconazole, with agreement rates of 100%, 97.4%, and 94.7%, respectively. Lower agreement, 73%, was observed for 5-flucytosine [7].

These findings show that the method used to assess susceptibility may influence the comparability of data. For future Moroccan studies, standardized methods should therefore be used and the interpretation criteria applied should be systematically specified.

Use of recognized standards, particularly those of CLSI or EUCAST, would improve comparability between centers. Data should also be presented separately for each species and each antifungal agent, to prevent differences in the composition of study populations from masking specific resistance profiles [3,7].

In this context, standardization of species-identification and antifungal susceptibility-testing methods is an essential step toward developing reliable national surveillance of antifungal resistance in Morocco.

4.5. Multidrug-resistance profiles and factors associated with resistance

Multidrug antifungal resistance is a particularly concerning issue in the management of invasive Candida infections. It corresponds to reduced or loss of susceptibility to several antifungal classes and may considerably limit therapeutic options. Internationally, increasing resistance to azoles and, more recently, the emergence of echinocandin resistance represent major public health concerns [4,5].

In Morocco, available data on multidrug resistance remain limited. However, the Tetouan study identified particularly concerning profiles among the 93 isolates studied. Two *C. krusei* isolates showed resistance to fluconazole as well as resistance to anidulafungin, corresponding to resistance to two antifungal classes [3]. Although these observations concern a limited number of isolates, they demonstrate that resistance profiles involving several classes can occur in populations studied in Morocco.

Antifungal resistance may be promoted by several factors. Previous exposure to antifungal agents is one of the main factors selecting for less susceptible strains. In patients with invasive candidiasis, other factors such as prolonged hospitalization, intensive care unit stay, use of intravascular catheters, surgery, exposure to broad-spectrum antibiotics, and immunosuppression may also increase the risk of Candida infection and create conditions favorable to the selection or spread of resistant strains [4].

However, currently available Moroccan studies do not allow the respective contribution of these factors to the emergence of resistance to be determined

precisely. Clinical data associated with microbiological results are still insufficiently reported, and longitudinal studies assessing changes in susceptibility within the same patient remain rare.

Future Moroccan studies should therefore systematically combine microbiological data with clinical and therapeutic information, including previous antifungal exposure, length of hospitalization, intensive care stay, presence of intravascular devices, and history of surgery. Such an approach would help identify factors associated with resistance and better guide prevention and antifungal stewardship strategies.

4.6. Emergence of Candida auris: a surveillance challenge for Morocco

Candida auris is currently one of the most concerning yeast species because of its ability to cause invasive infections, persist in the hospital environment, spread within healthcare facilities, and display resistance profiles involving several antifungal classes [5,8].

The situation in Africa is particularly concerning. A systematic review published in 2024 identified 19 studies concerning C. auris in Africa and reported at least 2,529 cases in six countries: South Africa, Kenya, Nigeria, Sudan, Egypt, and Algeria. Most cases originated from South Africa. Among 527 isolates for which susceptibility data were available, 91.3% were resistant to fluconazole, 20.5% to amphotericin B, and 1.7% to micafungin [5]. These findings illustrate the high resistance potential of this species and the need for active surveillance.

It should nevertheless be emphasized that the available African review did not report published data concerning C. auris cases in Morocco [5]. The absence of published cases does not, however, allow the conclusion that this species is absent from the country. Identification of C. auris can be difficult with some conventional methods, and diagnostic capacity for accurate identification of emerging species is not uniformly available in African laboratories [5].

This diagnostic difficulty represents an important challenge for Morocco. Some conventional biochemical methods may lead to misidentification of C. auris, particularly with closely related species such as *Candida haemulonii*. MALDI-TOF techniques with updated databases and molecular methods allow more reliable species identification [5].

In this context, improving microbiological identification capacity is an essential component of C. auris surveillance in Morocco. Updating databases used with MALDI-TOF systems, using molecular methods in reference laboratories, and establishing procedures for suspecting C. auris based on specific microbiological profiles could improve its detection [5].

Surveillance of C. auris should also include antifungal susceptibility testing. This approach is particularly important because of the high frequency of fluconazole resistance reported in African series [5]. However, resistance rates observed in Africa should not be directly extrapolated to the Moroccan population in the absence of specific national data.

Thus, even in the current absence of published data demonstrating circulation of C. auris in Morocco, the emergence of this species in several African regions justifies increased vigilance. Prospective surveillance of Candida isolates, particularly non-albicans species, could enable early detection of possible introduction or emergence in Moroccan healthcare facilities.

4.7. Main findings regarding antifungal resistance in Morocco

Available data allow several conclusions to be drawn regarding antifungal resistance in Morocco. First, Moroccan studies demonstrate the presence of isolates with reduced susceptibility or resistance to certain antifungal agents, particularly fluconazole and anidulafungin [3,6].

Second, resistance profiles involving several classes have been observed, particularly among *C. krusei* isolates in the Tetouan study [3]. However, these observations remain limited to small series and do not allow estimation of a national prevalence of multidrug resistance.

Third, comparison of Moroccan data is complicated by heterogeneity in the methods used for species identification and antifungal susceptibility testing [3,7]. Standardization of methods is therefore essential to improve epidemiological surveillance and allow reliable comparison of results between healthcare facilities.

Finally, the emergence of C. auris in Africa represents an additional risk that justifies strengthening diagnostic and surveillance capacity in Morocco [5,8]. The absence of published data on this species in Morocco should not be interpreted as evidence of its absence, but rather as an important gap in current knowledge.

5. DISCUSSION

The present review highlights the limited and heterogeneous nature of the available evidence on the epidemiology of *Candida* spp. Infections and antifungal resistance in Morocco. Although *Candida albicans* remains frequently identified, non-*albicans Candida* species represent a substantial proportion of isolates in several Moroccan clinical settings. Available studies also indicate the presence of reduced susceptibility or resistance to commonly used antifungal agents, including fluconazole and anidulafungin. However, the available evidence remains insufficient to establish

reliable national estimates of species distribution or antifungal resistance.

5.1. Main epidemiological findings

The available Moroccan studies suggest considerable variability in the epidemiology of *Candida* infections between healthcare facilities. In the Tetouan study, *C. albicans* accounted for 64.52% of 93 clinical isolates, while *C. glabrata*, *C. parapsilosis*, and *C. tropicalis* represented important proportions of the remaining isolates [3]. In contrast, the candidemia series from Fez reported a predominance of non-*albicans Candida* species, which accounted for 64.2% of isolates [6]. These differences should be interpreted cautiously, as they may reflect differences in patient populations, clinical settings, specimen types, study periods, and microbiological identification methods rather than true geographical differences.

The frequent identification of *C. albicans* in Moroccan studies confirms its continued importance as a major *Candida* species. Nevertheless, the substantial proportion of non-*albicans Candida* species observed in some settings is clinically relevant because these species may differ in their antifungal susceptibility profiles and may therefore have implications for therapeutic management [3,4,6]. The identification of nine *Candida* species in the Tetouan study, including *C. metapsilosis*, further illustrates the diversity of *Candida* isolates reported in Morocco and suggests that this diversity may be underestimated when identification methods have limited discriminatory capacity [3].

5.2. Heterogeneity of Moroccan epidemiological data

One of the main findings of this review is the substantial methodological heterogeneity among the available Moroccan studies. The studies differ in geographical location, study population, clinical setting, sample type, study period, species-identification methods, and antifungal susceptibility-testing procedures [3,6,7]. Consequently, direct comparison of species proportions or susceptibility rates between studies should be undertaken with caution.

This heterogeneity also limits the possibility of extrapolating findings from individual healthcare facilities to the Moroccan population as a whole. For example, the high proportion of non-*albicans Candida* reported in the Fez candidemia series may partly reflect the characteristics of patients treated at a university hospital, where a large proportion of cases occurred in intensive care [6]. Similarly, the Tetouan study included isolates collected from four healthcare facilities and from different clinical sources [3]. These differences underline the need for multicenter studies using standardized inclusion criteria and laboratory methods.

An estimated incidence of candidemia of approximately 5 cases per 100,000 inhabitants per year has been reported for Morocco [1]. However, this figure represents an estimate based on limited available epidemiological evidence and requires confirmation through robust national surveillance. Therefore, the current literature should be considered an important starting point rather than a definitive description of the national epidemiology of *Candida* infections.

5.3. Antifungal resistance: current evidence and limitations

The available Moroccan evidence indicates that reduced susceptibility and antifungal resistance occur among *Candida* isolates, but the magnitude of this problem at the national level remains uncertain. In the Tetouan study, elevated minimum inhibitory concentrations to fluconazole were observed in *C. albicans* and *C. glabrata*, while anidulafungin-resistant isolates were identified among *C. albicans*, *C. tropicalis*, and *C. krusei* [3]. The identification of *C. krusei* isolates showing resistance to more than one antifungal class is particularly noteworthy because such profiles may limit therapeutic options.

However, these findings should be interpreted in the context of the limited number of isolates investigated. In the Fez candidemia series, fluconazole susceptibility was reported at 70%; however, this finding cannot be extrapolated to the national level because of the limited sample size and the characteristics of the study population [6]. Differences in species distribution, study populations, and susceptibility-testing methods further complicate comparisons between studies.

The Rabat study also illustrates the importance of methodological standardization. Although high agreement was observed between the two agar diffusion methods for several antifungal agents, differences were reported for 5-flucytosine [7]. Such findings support the need for standardized laboratory procedures and clearly defined interpretation criteria when susceptibility data from different healthcare facilities are compared.

5.4. Implications of *Candida auris* emergence

The emergence of *Candida auris* in several African countries represents an additional concern for Morocco. The African systematic review identified at least 2,529 cases reported from six African countries, but no published Moroccan cases were identified among the studies included in that review [5]. However, the absence of published cases should not be interpreted as definitive evidence of the absence of *C. auris* in Morocco, particularly in the context of limited surveillance and diagnostic capacity.

The potential introduction or emergence of *C. auris* reinforces the importance of improving species identification and surveillance capacity. Reliable identification methods, including appropriately updated MALDI-TOF databases and molecular approaches when required, may facilitate the recognition of unusual or difficult-to-identify isolates [5]. Nevertheless, resistance

rates reported from other African countries should not be directly extrapolated to Morocco in the absence of country-specific surveillance data.

5.5. Strengths and limitations of the available evidence

The main strength of the available Moroccan literature is that studies from different regions provide complementary information on species distribution, candidemia, and antifungal susceptibility [3,6,7]. The recent use of molecular identification approaches also demonstrates the potential value of improved microbiological methods for characterizing *Candida* diversity in Morocco [3].

However, several limitations must be acknowledged. Most available studies are single-center or laboratory-based investigations with relatively limited sample sizes. Geographic coverage remains incomplete, and methodological heterogeneity prevents reliable quantitative synthesis of the available data. In addition, molecular characterization of antifungal resistance mechanisms remains limited, while clinical and epidemiological information is not systematically integrated with microbiological findings.

Overall, the available evidence supports the need for a coordinated approach to *Candida* surveillance in Morocco. Multicenter prospective studies using standardized species identification and antifungal susceptibility-testing methods would provide more reliable estimates of the burden of *Candida* infections and the frequency of antifungal resistance. Integration of microbiological, clinical, epidemiological, and, where possible, molecular data would also improve understanding of the distribution of *Candida* species and the emergence of resistant isolates.

6. Knowledge Gaps Regarding Candida spp. Infections in Morocco

Despite several studies conducted in different regions of Morocco, current knowledge has several important limitations. The first concerns the absence of representative national epidemiological data. The estimate of candidemia incidence proposed in 2022 was based on limited data, and the authors emphasized the need for national studies to confirm this estimate [1].

The second gap concerns the geographic coverage of studies. Available data mainly originate from a few hospital centers or university laboratories, particularly in Fez, Rabat, and Tetouan [3,6,7]. Some regions of Morocco remain poorly documented or undocumented, limiting the ability to assess possible geographic differences in species distribution and resistance profiles.

A third limitation concerns the heterogeneity of the populations studied. Some publications focus on candidemia, whereas others include different types of clinical isolates. Study populations may also differ according to age, hospital department, risk factors, and specimen type. This methodological diversity makes direct comparison of species proportions and susceptibility rates between studies difficult [3,6].

The fourth gap concerns identification methods. The use of conventional methods may limit the ability to distinguish certain closely related species. The experience of the Tetouan study, which identified nine species using a molecular approach, suggests that Candida diversity may be underestimated in some Moroccan series [3].

Finally, data concerning the molecular mechanisms of resistance remain very limited. Available studies mainly report phenotypic susceptibility or resistance profiles, without systematic characterization of the associated genetic mechanisms. The development of molecular approaches would nevertheless help clarify the emergence of resistance and determine whether certain mechanisms are associated with particular lineages or clones.

These gaps highlight the need for an integrated national approach combining epidemiological surveillance, accurate species identification, standardized antifungal susceptibility testing, and, whenever possible, molecular characterization of isolates displaying unusual resistance profiles.

7. Perspectives and Recommendations for Morocco

7.1. Establishment of multicenter epidemiological surveillance

Strengthening epidemiological surveillance is one of the main priorities for improving knowledge of *Candida spp.* infections in Morocco. Current data mainly rely on single-center studies or studies conducted in a limited number of facilities, which do not provide a representative estimate of the national situation [1,3,6].

Establishing a multicenter network involving university hospitals, regional hospitals, and microbiology laboratories would allow standardized collection of data on candidemia and other invasive candidiasis. Such a network could document the number of cases, patient characteristics, isolated species, risk factors, antifungal treatments used, and clinical outcomes.

Longitudinal surveillance would also make it possible to monitor changes in species distribution and to detect early increases in the frequency of non-albicans species or the emergence of unusual antifungal susceptibility profiles. This approach would be particularly important in the context of the global increase in antifungal resistance [4,5].

7.2. Standardization of species identification

Improving species identification is a second priority. Findings from Tetouan show that molecular approaches can reveal greater Candida species diversity than that observed using conventional methods [3].

The progressive adoption of high-performance identification methods in Moroccan laboratories would therefore be desirable. MALDI-TOF techniques, when available and properly updated, as well as molecular methods, can improve identification of species that are difficult to differentiate using conventional approaches.

This improvement is particularly important for detecting emerging species. It could help reduce identification errors and allow earlier detection of C. auris, whose identification may be difficult with some conventional methods [5].

7.3. Harmonization of antifungal susceptibility-testing methods

Standardization of antifungal susceptibility determination is another major priority. The study conducted in Rabat showed that good agreement could be obtained between certain diffusion methods used to test Candida isolates, while also demonstrating differences according to the antifungal agents evaluated [7].

To improve national data comparability, laboratories should favor validated methods and use clearly defined interpretation criteria. Use of CLSI or EUCAST standards, according to the method adopted by each laboratory or surveillance network, would in particular help harmonize interpretation of results.

Results should be reported separately for each species and each antifungal agent. This presentation is essential because an overall susceptibility rate for all *Candida spp.* may mask important differences between species. Particular attention should be given to fluconazole and echinocandins, given their therapeutic importance and the international emergence of resistance to these classes [3,4].

7.4. Strengthening Candida auris surveillance

Surveillance of C. auris should become an emerging priority for medical mycology in Morocco. This species has been identified in several African countries and has characteristics that favor its spread in healthcare facilities, together with concerning antifungal resistance profiles [5].

The African review published in 2024 did not report published cases of C. auris in Morocco [5]. However, the absence of reports does not exclude possible undetected presence. Surveillance should therefore rely on a strategy allowing suspected isolates to be identified and their identification to be confirmed in reference laboratories.

A national strategy could include microbiological criteria for suspecting C. auris, regular updating of databases used by automated identification systems, and confirmation of suspected isolates by MALDI-TOF or molecular methods when necessary [5].

When identification is confirmed, antifungal susceptibility testing and epidemiological characterization of isolates would be essential to investigate possible transmission links and adapt patient management.

7.5. Development of antifungal stewardship programs

Combating antifungal resistance cannot rely solely on microbiological surveillance. It must also include antifungal stewardship programs aimed at optimizing prescribing and limiting unnecessary or inappropriate exposure.

These programs should promote treatment appropriate to the identified species, susceptibility profile, and clinical context. Prompt microbiological sampling, species identification, and susceptibility testing can contribute to more targeted antifungal use.

In the Moroccan context, development of antifungal stewardship strategies could be integrated into existing programs addressing antimicrobial resistance. This approach should involve microbiologists, infectious disease specialists, intensivists, pharmacists, and other professionals involved in the management of patients with invasive candidiasis [4,8].

7.6. Development of multicenter and molecular research

The development of multicenter studies is a priority in order to obtain data more representative of the Moroccan situation. These studies should include different regions of the country and standardize inclusion criteria, identification methods, and antifungal susceptibility-testing procedures.

Prospective studies would be particularly useful for determining the true incidence of candidemia, identifying factors associated with mortality and resistance, and monitoring changes in susceptibility profiles over time. Clinical data should be combined with microbiological data to identify risk factors for resistance.

Furthermore, the use of molecular biology techniques could allow characterization of resistance mechanisms in isolates with unusual profiles. Such an approach could specifically investigate mechanisms associated with azole and echinocandin resistance and identify possible clonal relationships between isolates from different patients or healthcare facilities.

7.7. Toward an integrated national surveillance system

In the longer term, the objective could be to develop an integrated national surveillance system for candidiasis and antifungal resistance. This system should combine clinical, microbiological, and epidemiological data from different healthcare facilities.

Such a system would make it possible to monitor the frequency of the main Candida species, the geographic distribution of infections, antifungal susceptibility trends, and the emergence of species such as C. auris. It could also provide useful data for developing therapeutic recommendations adapted to the Moroccan context.

Finally, implementation of national surveillance would transform currently fragmented data into comparable and actionable epidemiological information. It would therefore constitute an essential tool for anticipating the evolution of antifungal resistance and improving the management of Candida infections in Morocco [1,4,8].

8. CONCLUSION

Candida spp. infections constitute an important health problem in Morocco, but their true burden remains difficult to quantify because of the limited number of epidemiological studies and the absence of systematic national data. Available publications show that *C. albicans* remains frequently isolated, while non-albicans species account for a substantial proportion of isolates in several clinical settings [1,3,6].

Available data also demonstrate the presence of isolates with reduced susceptibility or resistance to certain antifungal agents, particularly fluconazole and anidulafungin [3,6]. Resistance profiles involving several classes have also been observed in some series, but their true national frequency remains unknown. The heterogeneity of microbiological methods used is an additional important limitation when comparing results between studies [3,7].

The emergence of C. auris in Africa represents an additional challenge. Although no published Moroccan case was identified in the currently available African data, the spread of this species in several countries on the continent and its resistance profiles justify strengthening surveillance and diagnostic capacity in Morocco [5,8].

In this context, establishing multicenter and standardized surveillance, combining accurate species identification, harmonized antifungal susceptibility testing, collection of clinical data, and, whenever possible, molecular characterization of resistant isolates, appears to be a priority. Development of antifungal stewardship programs should complement this strategy in order to limit selection and spread of resistance.

Thus, improving knowledge of Candida infections in Morocco requires a coordinated approach combining surveillance, microbiological diagnosis, clinical and molecular research, and antifungal stewardship policies. Development of such strategies would make it possible to better characterize the true burden of candidiasis, detect emerging resistance at an early stage, and improve patient management at the national level.

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