Prevalence, Species Distribution and Antifungal Susceptibility Profile of *Candida* Species Isolated from Bloodstream of Critical Care Unit Patients in a Tertiary Care Hospital in Kenya

Danait Andemichael Solomon[1]*, Andrew K. Nyerere[1], Alice Kanyua[2], Caroline Wangari Ngugi[1]

[1]Department of Medical Microbiology, Jomo Kenyatta University of Agriculture and Technology, 62000-00200, Nairobi, Kenya
[2]Nairobi Hospital, 30026-00100, Nairobi, Kenya
Email: *paunyt16@gmail.com

Abstract

The upsurge of candidemia in the past years has been an immense encumbrance on public health and the number of deaths caused by candidemia particularly in critical care unit patients is devastating. *Candida* species harbor a 30% - 60% mortality rate and compared to stable people or those with less serious illnesses, this ranges from 60% to 80% of those who are chronically ill patients. Grounded on a recent report from a tertiary care hospital in Kenya showing the emergence of previously unobserved species: *Candida auris*, this study aimed to determine the prevalence, species distribution, and antifungal susceptibility profile of candidemia in critical care unit patients of the hospital. 378 Critical Care Unit patients were enrolled for the study from January 2019 to January 2020. Positive archived isolates were sub-cultured using Saboraud Dextrose Agar. *Candida* species were identified utilizing API20C AUX and Vitek-2. Antifungal susceptibility testing was conducted using the Liofilchem MIC Test strip. Out of 378 patients, thirty-one presented a positive culture for *Candida* species. The prevalence of Candidemia was **8.2%** with **9 (29.03%)** *Candida auris*, **8 (25.81%)** *Candida albicans*, **6 (19.35%)** *Candida parapsilosis*, **3 (9.68%)** *Candida famata*, **3 (9.68%)** *Candida tropicalis*, **1 (3.23%)** *Candida duobushaemolumonii*, and **1 (3.23%)** *Candida lusitaniae*. A resistance pattern to Fluconazole was observed among *Candida auris* and *Candida parapsilosis*, and resistance to Flucytosine was observed in *Candida tropicalis*, whereas susceptible MIC values were obtained for the other drugs. There is an increase in candidemia among critical care unit patients in the health facility posing a public health challenge. Moreover, the onset of new species *Candida auris* which is unprecedented in Kenya warrants enhanced infection control, and the uniform resistance of *Candida auris*, *Candida pa-*

rapsilosis, and *Candida tropicalis* towards Fluconazole and Flucytosine necessitate constant drug monitoring for empirical treatment regime. In contrast, the high potency of Echinocandins and Amphotericin-B demonstrate them as the drug of choice.

Keywords

Critical Care Unit, *Candida* Species, *Candida auris*, Candidemia, Antifungal Susceptibility

1. Introduction

Fungal infections, explicitly *Candida* species have been the major cause of mortality and morbidity in hospitalized patients and predominantly in the Critical Care Units [1] [2]. *Candida* species reside inside the host as normal flora and dwell in the oral cavity of healthy human beings, however, in immunocompromised patients, these commensal microorganisms are capable of causing disease [3]. Prominently causing nosocomial infections, *Candida* spp. rates the fourth in causing all bloodstream infections and third of bloodstream infections in critically ill patients [4]. Worldwide in tertiary care hospitals, those results attribute to mortality rates of 15% ± 35% in adults and 10% ± 15% in neonates [5]. Based on studies done in several hospitalized patients, including intensive care unit patients, candidemia causes mortality of 47% among the patients [6].

In the USA, *Candida* species are considered as the third or fourth most causative agent of healthcare-acquired infections [5] and lead to a 30% - 60% mortality rate of hospitalized patients [6]. These are associated with changes in the individuals' physiology and immunocompromised state which results in severe infections [3]. Several risk factors of the origin of the *Candida* infections in hospitalized patients could be endogenously brought by the patients themselves or could be from instruments in the hospital. It might also be contributed to contaminations of hospital surroundings or cross-infection from health workers which would attribute to the exogenous cause [5] [7] [8]. Candidemia is frequently seen among those infections, especially with patients in Critical Care Units [5]. Moreover, as a result of these infections, expanded costs in healthcare are incurred, ranging from $35,000 to $68,000 for a single candidemia case in the United States [8].

Patterns of anti-fungal drug resistance by *Candida* species have been causing stern public health challenges and were encompassed in CDC's 2013 Antibiotic Resistance Threat Report [9] [10]. Critically ill patients undergo invasive treatments and consume several anti-fungal drugs, however, results of anti-fungal resistance have been causing epidemiological unsustainability [11] [12]. Certain *Candida* strains are progressively resistant to commonly used antifungal drugs. Based on recent data from CDC, a discernable shift is observed in candidemia occurrences with augmented drug resistance to first-line and second-line anti-

fungal drugs such as Azoles and Echinocandins [10]. In the United States, 46,000 hospitalized patients face *Candida* infections each year, and approximately 30% of those who harbor drug-resistant *Candida* species are estimated to die during hospitalization [10]. Several reports state that the increase of anti-fungal resistance has been resulting in high mortality and morbidity in critical care patients [2] [13]. This has contributed to many deaths due to *Candida* infections in the past years [11] [12].

According to literature from Kenya, the significant agent for hospital infections is considered to be *Candida albicans* [14] [15]. However, *Candida auris* has recently been observed frequently in a tertiary care hospital in Nairobi, Kenya grounded on several lab reports from ICU and HDU patients. Swift dissemination of this multi-drug resistant species is discerned in different parts of the world [2]. It was first reported in 2009 and since then it has been detected in five continents causing serious hospital-acquired infections [2]. A study conducted in Kenya recorded a drug resistance pattern of *Candida albicans* and *Candida parapsilosis* isolates towards fluconazole [14] [16], however, drug susceptibility patterns of the novel species, *Candida auris* remains unreported up-to-date in Kenya. Therefore, the aim of this study was to determine the prevalence and antifungal susceptibility profile of *Candida* species among critical care unit patients of the hospital.

2. Materials and Methods

2.1. Study Area

The study was conducted in a tertiary care hospital in Nairobi, Kenya. The hospital has been officially operational since 9 April 1954 and is located on Argwings Kodhek Road, in the neighborhood of Upper Hill, in Kenya's capital city of Nairobi. The hospital is a high capacity hospital and serves different patients from the whole country [17].

2.2. Study Population

The study participants were enrolled from the intensive care unit and highly dependent unit of the hospital. The study population included patients of all age groups who had been requested for blood culture by a physician. A total of 378 patients based on Naing *et al.* (2006) [18] formula were tested from January 2019 to January 2020 for *Candida* bloodstream infection in ICU and HDU of Nairobi Hospital. Out of those thirty-one (31), patients showed positive culture for *Candida* and the isolates were archived.

$$n = \frac{Z^2 (P)(1-P)}{d^2}$$

where: n = Sample size.

Z = The confidence interval at 95% (1.96).

P = Estimate of the proportion or anticipated prevalence used 12.42% candidiasis from a population-based study in Africa [19].

d = margin of error at 5% (0.05).

$$n = \frac{Z^2(P)(1-P)}{d^2} = \frac{1.96^2(0.1242)(1-0.1242)}{0.05^2} = 167$$

2.3. Culture of Isolates

The archived isolates which had positive blood culture underwent a sub culturing method using Saboraud dextrose agar (SDA). Isolates that were stored in glycerol were inoculated in a Petri dish plate with a Saboraud Dextrose media and they were incubated in 37°C for 24 - 48 hours. The appearance of creamy white colonies with soft texture was considered positive for *Candida* growth.

2.4. API 20C AUX and VITEK-2 Tests

A confirmatory test was done for the cultured isolates to identify the specific species using API 20C AUX (Biomerieux, USA). Isolated *Candida* colonies were inoculated in the API 20C cupules for positive or negative growth check in the 19 assimilation tests [20]. Incubation of the strip was done for 48 and 72 hours in 31°C, after which the reactions were compared to the first cupule containing negative control. The numbers recorded were interpreted using apiweb™ software (Biomerieux, SA). Isolates that were identified as *Candida famata* by API 20C AUX (Biomerieux, USA) were confirmed using VITEK-2 version 8.1 (Biomerieux, USA) to differentiate whether they were truly *Candida famata* or they were misidentified *Candida auris* or *Candida duobushaemolumonii*. The test was done following the manufacturer's instructions for VITEK-2 (Biomerieux, USA) [21].

2.5. Antifungal Susceptibility Testing

Anti-fungal drug susceptibility was performed using Liofilchem MIC test strip (Liofilchem S.R.I., Italy) for Fluconazole, Micafungin, Caspofungin, Amphotericin-B, Flucytosine, and Voriconazole [22]. The Liofilchem MIC test strip (Liofilchem S.R.I., Italy) is a non-penetrating plastic material designed to have 15 two-fold dilutions of antibiotic concentrations [22]. The strip was placed in a Saboraud Dextrose Agar (SDA) inoculated with 0.5 McFarland pure colonies' suspension of the isolated species. Subsequently, the agar plates were incubated at 37°C and observed for Minimum Inhibitory Concentration (MIC) reading after 24 hours. The interpretation was done classifying the organisms as sensitive or resistant based on CLSI MA-27 guidelines [23].

Quality control of the Identification and Antifungal Susceptibility tests in this study was maintained using reference strains of *Candida albicans* ATCC: 14053 and *Candida parapsilosis* ATCC 22019.

2.6. Data Analysis

Data collected were documented in Microsoft Excel (Microsoft Corp, USA) before transferring to SPSS version 20 (IBM, USA) for analysis. Descriptive Statis-

tics was done to determine the frequencies of the species distribution. Cross Tabulation was used to determine the Prevalence of *Candida* species in relation to age, ward, and gender. Chi-square was used for the level of significance. T-test was used to calculate the p-value association between HDU and ICU based on age, gender, and prevalence. Minimum and maximum susceptibility values were calculated for all the drugs tested to obtain the MIC range.

3. Results

3.1. Characteristics of Study Population

A total of 378 patients were tested from January 2019 to January 2020. The study population was patients admitted to ICU and HDU of the tertiary care hospital. Out of 378 patients, 203 were from ICU and 105 from HDU. The median age for ICU was 55 years (2 mon-95 years) and 61 years (16 - 101 years) in HDU with a p-value of 0.0534 (Table 1). The majority of the patients were males at 158 (57.9%) and 60 (57.1%), while females were 115 (42.1%) and 45 (42.9%) in ICU and HDU respectively. The prevalence of *Candida* infections was more prominent in ICU with a total of 24 (77.4%) positive cases, with HDU having a lower prevalence of 7 (22.6%) positive cases.

3.2. Prevalence and Distribution of *Candida* Species

Out of the 378 patients tested thirty-one (31) patients were found to have candidemia comprising **8.2%** of the total patients. The highest prevalence was *Candida auris* at 29.03% and the lowest prevalence in *Candida duobushaemolumonii* and *Candida lusitaniae*, at 3.23% each (Figure 1).
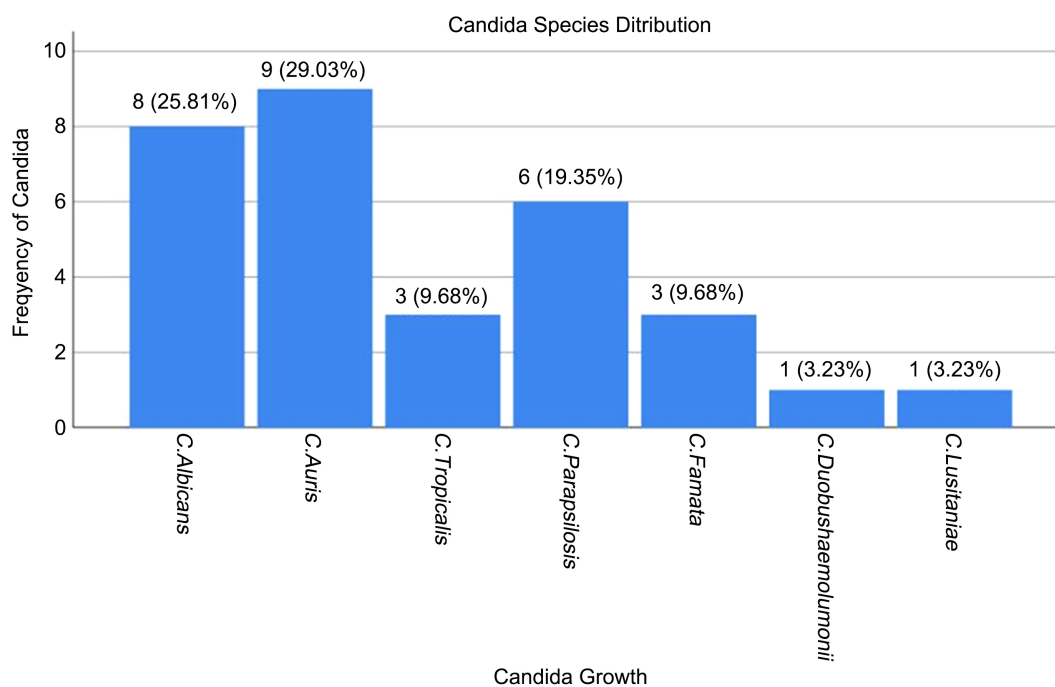

Figure 1. Distribution of *Candida* species from the API 20C AUX result.

An overall higher prevalence was observed in ICU compared with HDU. In patients under the age of 20 years, there were two positive cases in male patients of HDU. In patients between the age of 20 - 40, there were four positive cases, three being among the male patients and 1 in the female patient of ICU. A total of seven patients (male and female) were positive for *Candida* species in ICU in the age group of 41 - 60 while only two male patients were positive in HDU. The most noteworthy prevalence was seen in patients above the age of 60 with females comprising higher incidences of candidemia at 29.2% (7) while male patients had lesser prevalence at 25% (6) in ICU. In contrast, males had a higher occurrence at 28.5% (2) than females at 14.3% (1) in HDU (Table 2). A chi-square test on both sides showed there was no significant association of the prevalence results with age, gender, and ward giving a p-value of 0.543, 0.401 and 0.436, respectively.

Table 1. Characteristics of the study population.

		ICU	HDU	P-VALUE
Age				
Median (Range)		55 years (2 months - 95 years)	61 years (16 years - 101 years)	0.0534
Gender	M	158	60	0.908
	F	115	45	
Prevalence (%)		24 (77.4%)	7 (22.6%)	0.319

Table 2. Distribution of *Candida* species based on age, ward, and gender.

ICU								
Age Group (Years)	<20		20 - 40		41 - 60		>60	
Gender	M	F	M	F	M	F	M	F
Organisms								
Candida auris	0 (0%)	0 (0%)	1 (4.2%)	1 (4.2%)	0 (0%)	0 (0%)	0 (0%)	4 (16.6%)
Candida albicans	0 (0%)	0 (0%)	1 (4.2%)	0 (0%)	0 (0%)	2 (8.3%)	2 (8.3%)	2 (8.3%)
Candida parapsilosis	0 (0%)	0 (0%)	1 (4.2%)	0 (0%)	2 (8.3%)	0 (0%)	2 (8.3%)	0 (0%)
Candida tropicalis	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (4.2%)	1 (4.2%)
Candida famata	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (8.3%)	0 (0%)	1 (4.2%)	0 (0%)
Candida duobushaemolumonii	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Candida lusitaniae	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (4.2%)	0 (0%)	0 (0%)
HDU								
Age Group (Years)	<20		20 - 40		41 - 60		>60	
Gender	M	F	M	F	M	F	M	F
Organisms								
Candida auris	1 (14.3%)	0 (0%)	0 (0%)	0 (0%)	1 (14.3%)	0 (0%)	1 (14.3%)	0 (0%)
Candida albicans	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (14.3%)	0 (0%)
Candida parapsilosis	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1(14.3%)
Candida tropicalis	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (14.3%)	0 (0%)	0 (0%)	0 (0%)
Candida famata	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Candida duobushaemolumonii	1 (14.3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Candida lusitaniae	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

3.3. Antifungal Susceptibility of Isolated *Candida* Species

Antifungal Drug Susceptibility tests were accomplished for the 31 isolates against Fluconazole, Voriconazole, Micafungin, Caspofungin, Amphotericin B, and Flucytosine covering the three-drug classes of anti-fungal drugs. All *Candida* isolates in the study were sensitive to Micafungin, Caspofungin, Voriconazole, and Amphotericin B. However, *Candida auris* and *Candida parapsilosis* demonstrated complete resistance to Fluconazole whereas *Candida tropicalis* strains were resistant to Flucytosine (Table 3). The lowest MIC value was observed in Echinocandins, Micafungin at 0.023 μg/mL for *Candida famata*. Meanwhile, the highest MIC value obtained was in fluconazole resistance at 256 μg/mL and was observed in *Candida auris* and *Candida parapsilosis* strains. The test was conducted utilizing the Liofilchem MIC test strip and was interpreted based on the classification of CLSI breakpoints [23].

4. Discussion

This study documents the prevalence of candidemia among patients admitted to the critical care unit of a tertiary care hospital in Nairobi, Kenya. The results showed a higher prevalence of 8.2% compared to a study previously conducted in Kenya showing a rate of 5 cases of candidemia per 100,000 patients [15]. The increased candidemia could be attributed to the number of invasive measures taken in hospitalized patients when handling their medical care and the immunocompromised state of the patients also plays a role in the severity of the infection. This ascent in prevalence demonstrates a public health challenge, especially to those who are hospitalized in ICU and HDU and have relatively severe illnesses.

Existing publications of *Candida* infections in Kenya states that the most frequently isolated *Candida* species was *Candida albicans* [14] [16], however, this study highlights the onset of the new species, *Candida auris* in high prevalence. *Candida auris* was first isolated in 2009 and recorded cases are portrayed by elevated levels of total mortality [2] [24] [25] and high antifungal resistance rates [26]. Of note, the vast majority of the infections reported involved patients that are critically ill [24] [27]. Furthermore, identification has been difficult by microbiological techniques [2] [28] [29] notwithstanding *Candida auris* being one of the most prevalent species which increases the risk of misidentification and hence improper treatment. *Candida auris*'s high virulence [30] [31], a profile of multi-drug resistance [32], and rapid outbreak and global propagation marks it as a worldwide threat [2].

The antifungal susceptibility tests performed showed a susceptible profile of all isolates towards Echinocandins and Amphotericin B and Voriconazole. A study conducted in a tertiary care hospital in Italy, however, showed a resistance pattern of *Candida albicans* towards Voriconazole [33]. Besides, as evidenced in certain reports *Candida* species are usually susceptible to Amphotericin-B as an antifungal drug [33], and the resistance to Echinocandins is in very low percentages

Table 3. Anti-fungal susceptibility results and minimum inhibitory concentration (MIC) range against six antifungal drugs as evaluated by the Liofilchem MIC Test strip and distribution of isolates of *Candida* spp.

Candida Species	No. (%) Sensitivity Profile			
	Total (%)	MIC Range (µg/mL)	Sensitive (%)	Resistant (%)
Candida auris	9 (29.03%)			
Fluconazole		>64 - 256	0	9 (100%)
Voriconazole		0.19 - 1.5	9 (100%)	0
Caspofungin		0.19 - 1	9 (100%)	0
Micafungin		0.06 - 1	9 (100%)	0
Amphotericin-B		0.064 - 0.75	9 (100%)	0
Flucytosine		0.50 - 1	9 (100%)	0
Candida albicans	8 (25.81%)			
Fluconazole		0.5 - 4	8 (100%)	0
Voriconazole		0.125 - 1	8 (100%)	0
Caspofungin		0.012 - 0.94	8 (100%)	0
Micafungin		0.06 - 1	8 (100%)	0
Amphotericin-B		0.25 - 0.50	8 (100%)	0
Flucytosine		1 - 1.5	8 (100%)	0
Candida tropicalis	3 (9.68%)			
Fluconazole		1 - 1	3 (100%)	0
Voriconazole		0.125 - 0.75	3 (100%)	0
Caspofungin		0.016 - 0.25	3 (100%)	0
Micafungin		0.50 - 0.75	3 (100%)	0
Amphotericin-B		0.38 - 0.50	3 (100%)	0
Flucytosine		>32	0	3 (100%)
Candida famata	3 (9.68%)			
Fluconazole		0.50 - 1	3 (100%)	0
Voriconazole		0.094 - 1	3 (100%)	0
Caspofungin		0.25 - 1	3 (100%)	0
Micafungin		0.023 - 0.38	3 (100%)	0
Amphotericin-B		0.047 - 0.5	3 (100%)	0
Flucytosine		0.38 - 1	3 (100%)	0
Candida parapsilosis	6 (19.35%)			
Fluconazole		>64 - 256	0	6 (100%)
Voriconazole		0.047 - 1	6 (100%)	0
Caspofungin		0.50 - 1	6 (100%)	0
Micafungin		0.25 - 1	6 (100%)	0
Amphotericin-B		0.25 - 1	6 (100%)	0
Flucytosine		0.75 - 1	6 (100%)	0

Continued

Candida Lusitaniae	1 (3.23%)			
Fluconazole		-	1 (100%)	0
Voriconazole		-	1 (100%)	0
Caspofungin		-	1 (100%)	0
Micafungin		-	1 (100%)	0
Amphotericin-B		-	1 (100%)	0
Flucytosine		-	1 (100%)	0
Candida Duobushaemolumonii	1 (3.23%)			
Fluconazole		-	1 (100%)	0
Voriconazole		-	1 (100%)	0
Caspofungin		-	1 (100%)	0
Micafungin		-	1 (100%)	0
Amphotericin-B		-	1 (100%)	0
Flucytosine		-	1 (100%)	0

Classification of sensitive and resistant according to the rules of the Clinical and Laboratory Standards Institute M27-A3 [23]: Fluconazole (S: 8 µg/mL; R: 64 µg/ml); Voriconazole (S: 1 µg/mL; R: 4 µg/mL); Flucytosine (S: 4 µg/mL; R: 32 µg/mL); Amphotericin B (S < 1 µg/mL; R > 2 µg/mL); Echinocandins (S < 2 µg/ml, sensitive breakpoint only). S, sensitive; R, resistant.

to *Candida albicans* and non-albicans except for *Candida glabrata [34]*. Moreover, a study conducted in Kenya showed a resistance pattern of *Candida albicans* towards Fluconazole at a rate of 26% [16]. Interestingly, there was no isolate of *Candida albicans* showing resistance to any of the drug classes used in this study. Aware of the latter assertion, the increased susceptibility of *Candida albicans* might indicate the enhancement of drug regime towards this species as research was done massively targeting it in Kenya [14] [15] [35].

Furthermore, an increased resistance pattern in three species was observed in this study. *Candida auris* was seen to have a high resistance pattern up to 256 µg/ml for fluconazole indicating no susceptible isolate from all the 9 isolates tested against fluconazole. The power of *Candida auris* to establish uniform resistance to fluconazole might increase the mortality rates of immunocompromised patients [2] [36]. This study additionally acquired a drug resistance pattern towards Flucytosine by *Candida tropicalis* with 3 (100%) isolates showing increased MIC values as was classified resistant by CLSI breakpoints. A study conducted in Paris indicates the increased resistant activity of *Candida tropicalis* towards Flucytosine [37], however, this has not been documented in Kenya previously. In spite of certain reports expressing *Candida parapsilosis* as frequently susceptible to azoles [38] [39], several pieces of research have indicated its increased resistance towards Fluconazole [23] [40] [41]. In this study, all isolated *Candida parapsilosis* were discovered resistant to Fluconazole.

The drug susceptibility results exhibited a resistance pattern in the entirety of the isolated species of *Candida parapsilosis*, *Candida auris*, and *Candida tropica-*

lis. Critically ill patients face the threat of morbidity and mortality as a result of the wide use of broad-spectrum anti-fungal drugs where there is a development of resistance by *Candida* species [2]. Inherent causes of resistance are also noted on top of the usual acquired pattern of drug resistance after antifungal drugs are administered to patients [2] [42]. This intrinsic nature of resistance is usually seen in *non-albicans*, as is documented in this study. Despite the fact that the onset of drug resistance happens in several cases the pattern of complete resistance in all three species might show transmission of the *Candida* species among the patients. Infection control in patients with *Candida* has never been a challenge previously since it was comprehended that *Candida* infections derive essentially from the translocation of host flora to usually sterile locations, such as the bloodstream. Similar patterns of resistance, however, may suggest that the same strain circulates across the patients attributed to hospitalized patients' transmission as is confirmed by numerous studies [43] [44] [45]. The increased resistance of the *Candida* species inclines a high risk to hospitalized patients and might attribute to increased death rate particularly in critically ill patients.

5. Conclusion

There are increased candidemia cases in the critical care units of the health facility and dependent on the outcomes acquired, the study determined an exceptionally pervasive occurrence of new *Candida* species: *Candida auris*, and its drug-resistant property as a high threat to the public. Thus, measures ought to be taken to control the infection and transmission to diminish the mortality and morbidity of critically ill patients. Additionally, Echinocandins showed high potency as antifungal drugs against *albicans* and non-*albicans* whereas Fluconazole and Flucytosine were proved to be less effective drugs in the conspicuously seen species of *Candida auris*, *Candida parapsilosis*, *and Candida tropicalis*. Consequently, for an appropriate drug regime, physicians should be alert of the drug susceptibility patterns of *Candida* species in the locality before prescribing any of the anti-fungal drugs. All in all, the onset of new species and increased drug resistance patterns warrant constant drug monitoring. As this study was limited to Nairobi, researches of *Candida* blood stream infections in critical care units should be done in hospitals in other parts of Kenya for a comprehensive and updated prevalence study and to monitor the spread of *Candida auris* in the country. Moreover, the molecular basis of resistance should also be established in future studies for enhanced treatment.

Acknowledgements

Mr. James Gachugia for his assistance in editing the manuscript.

Funding

Authors Contribution

DAS, AKN, AK, CWN conceived and designed the study. DAS performed laboratory analysis and data analysis. DAS drafted the manuscript. All authors read, reviewed, and approved the final manuscript.

Ethical Approval

Ethical approval was obtained from Jomo Kenyatta University of Agriculture and Technology's Ethics Review Committee and the study site hospital's Ethics Review Committee. No patient was recruited solely for the study, but rather the study was part of the normal patient care process. Access to the data was strictly prohibited to maintain the confidential information of the patient. Patient Identification was done in a way that doesn't disclose the real information of the patient to avoid the leak of patient history.

Data Availability

The data can be provided upon request from the corresponding author.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

[1] Kullberg, B.J. and Arendrup, M.C. (2015) Invasive Candidiasis. *The New England Journal of Medicine*, **373**, 1445-1456.

[2] Cortegiani, A., Misseri, G., Fasciana, T., Giammanco, A., Giarratano, A. and Chowdhary, A. (2018) Epidemiology, Clinical Characteristics, Resistance, and Treatment of Infections by *Candida auris*. *Journal of Intensive Care*, **6**, Article No. 69. https://doi.org/10.1186/s40560-018-0342-4

[3] Sardi, J.C.O., Duque, C., Hofling, J.F. and Goncalves, R.B. (2012) Genetic and Phenotypic Evaluation of *Candida albicans* Strains Isolated from Subgingival Biofilm of Diabetic Patients with Chronic Periodontitis. *Medical Mycology*, **50**, 467-475. https://doi.org/10.3109/13693786.2011.633233

[4] Sandt, C., Sockalingum, G.D., Aubert, D., Lepan, H., Lepouse, C., Jaussaud, M., *et al.* (2003) Use of Fourier-Transform Infrared Spectroscopy for Typing of *Candidaalbicans* Strains Isolated in Intensive Care Units. *Journal of Clinical Microbiology*, **41**, 954-959. https://doi.org/10.1128/JCM.41.3.954-959.2003

[5] Al-Obaid, K., Asadzadeh, M., Ahmad, S. and Khan, Z. (2017) Population Structure and Molecular Genetic Characterization of Clinical *Candida tropicalis* Isolates from

a Tertiary-Care Hospital in Kuwait Reveal Infections with Unique Strains. *PLoS ONE*, **12**, e0182292. https://doi.org/10.1371/journal.pone.0182292

[6] Bonfim-Mendonça, P.D.S., Fiorini, A., Shinobu-Mesquita, C.S., Baeza, L.C., Fernandez, M.A. and Svidzinski, T.I.E. (2013) Molecular Typing of *Candida albicans* Isolates from Hospitalized Patients. *Revista do Instituto de Medicina Tropical de São Paulo*, **55**, 385-391. https://doi.org/10.1590/S0036-46652013000600003

[7] Ahmad, S. and Khan, Z. (2012) Invasive Candidiasis: A Review of Nonculture-Based Laboratory Diagnostic Methods. *Indian Journal of Medical Microbiology*, **30**, 264-269. https://doi.org/10.4103/0255-0857.99482

[8] Suleyman, G. and Alangaden, G.J. (2016) Nosocomial Fungal Infections Epidemiology, Infection Control, and Prevention. *Infectious Disease Clinics of North America*, **30**, 1023-1052. https://doi.org/10.1016/j.idc.2016.07.008

[9] Toda, M., Williams, S.R., Berkow, E.L., Farley, M.M., Harrison, L.H., Bonner, L., *et al.* (2019) Population-Based Active Surveillance for Culture-Confirmed Candidemia—Four Sites, United States, 2012-2016. *Morbidity and Mortality Weekly Report-Surveillance Summaries*, **68**, 1-15. https://doi.org/10.15585/mmwr.ss6808a1

[10] Centers for Disease Control and Prevention (2013) Antibiotic Resistance Threats in the United States, 2013. US Centers for Disease Control and Prevention, Atlanta.

[11] Ghahri, M., Mirhendi, H., Zomorodian, K. and Kondori, N. (2013) Identification and Antifungal Susceptibility Patterns of *Candida* Strains Isolated from Blood Specimens in Iran. *Archives of Clinical Infectious Diseases*, **8**, e14529. https://doi.org/10.5812/archcid.14529

[12] Sadrossadati, S.Z., Ghahri, M., Fooladi, A.A.I., Sayyahfar, S., Beyraghi, S. and Baseri, Z. (2018) Phenotypic and Genotypic Characterization of *Candida* Species Isolated from Candideamia in Iran. *Current Medical Mycology*, **4**, 14-20. https://doi.org/10.18502/cmm.4.2.64

[13] Negri, M., Silva, S., Henriques, M. and Oliveira, R. (2012) Insights into *Candida tropicalis* Nosocomial Infections and Virulence Factors. *European Journal of Clinical Microbiology & Infectious Diseases*, **31**, 1399-1412. https://doi.org/10.1007/s10096-011-1455-z

[14] Kangogo, M., Wanyoike, M., RevathiI, G. and Bii, C. (2011) Phenotypic Characterization of *Candida albicans* from Clinical Sources in Nairobi. *African Journal of Health Sciences*, **19**, 19-23.

[15] Guto, J.A., Bii, C.C. and Denning, D.W. (2016) Emerging Problems in Infectious Diseases Estimated Burden of Fungal Infections in Kenya. *Journal of Infection in Developing Country*, **10**, 777-784. https://doi.org/10.3855/jidc.7614

[16] Ooga, V.B., Gikunju, J.K. and Bii, C.C. (2011) Characterization and Antifungal Drug Susceptibility of Clinical Isolates of *Candida* Species. *African Journal of Health Sciences*, **19**, 76-83.

[17] The Nairobi Hospital (2016) Annual Report & Financial Statements. The Nairobi Hospital, Nairobi.

[18] Naing, L., Winn, T. and Rusli, B.N. (2006) Pratical Issues in Calculating the Sample Size for Prevalence Studies. *Archives of Orofacial Sciences*, **1**, 9-14.

[19] Omrani, A.S., Pecen, L., Hajek, P., Raghubir, N. and Zigmond, J. (2014) Prevalence of Invasive and Superficial *Candida* Infections in Africa and Middle East: A Systematic Review and Meta-Analysis. *114th Meeting of the American Society for Microbiology*, Boston, 17-20 May 2014, No. 1273.

[20] BioMérieux SA (2010) 20 C AUX. BioMérieux SA, Marcy-l'Etoile, 1-3.

[21] Pincus, D.H. (2013) Microbial Identification Using the Biomerieux VITEK 2 System. In: Miller, M.J., Ed., *Encyclopedia of Rapid Microbiological Methods*, 1-32.

[22] Liofilchem (2018) Liofilchem MIC Test Strip. Liofilchem, Waltham.

[23] Cantón, E., Espinel-Ingroff, A. and Pemán, J. (2009) Trends in Antifungal Susceptibility Testing Using CLSI Reference and Commercial Methods. *Expert Review of Anti-Infective Therapy*, **7**, 107-119. https://doi.org/10.1586/14787210.7.1.107

[24] Rudramurthy, S.M., Chakrabarti, A., Paul, R.A., Sood, P., Kaur, H., Capoor, M.R., *et al.* (2017) *Candida auris Candida*æmia in Indian ICUs: Analysis of Risk Factors. *Journal of Antimicrobial Chemotherapy*, **72**, 1794-1801. https://doi.org/10.1093/jac/dkx034

[25] Sekyere, J.O. (2018) *Candida auris*: A Systematic Review and Meta-Analysis of Current Updates on an Emerging Multidrug-Resistant Pathogen. *MicrobiologyOpen*, **7**, e00578.

[26] Ben-Ami, R., Berman, J., Novikov, A., Bash, E., Shachor-Meyouhas, Y., Zakin, S., Maor, Y., Tarabia, J., Schechner, V., Adler, A. and Finn, T. (2018) Multidrug-Resistant *Candida haemulonii* and *C. auris*, Tel Aviv, Israel. *Emerging Infectious Diseases*, **23**, 195-203. https://doi.org/10.3201/eid2302.161486

[27] Chowdhary, A., Voss, A. and Meis, J.F. (2016) Multidrug-Resistant *Candida auris*: 'New Kid on the Block' in Hospital-Associated Infections? *Journal of Hospital Infection*, **94**, 209-212. https://doi.org/10.1016/j.jhin.2016.08.004

[28] Kathuria, S., Singh, P.K., Sharma, C., Prakash, A., Masih, A., Kumar, A., *et al.* (2015) Multidrug-Resistant *Candida auris* Misidentified as *Candida haemulonii*: Characterization by Matrix-Assisted Laser Desorption Ionization-Time of Flight Mass Spectrometry and DNA Sequencing and Its Antifungal Susceptibility Profile Variability by Vitek 2, CLSI Broth Microdilution, and Etest Method. *Journal of Clinical Microbiology*, **53**, 1823-1830. https://doi.org/10.1128/JCM.00367-15

[29] Kim, T.-H., Kweon, O.J., Kim, H.R. and Lee, M.-K. (2016) Identification of Uncommon *Candida* Species Using Commercial Identification Systems. *Journal of Microbiolog and Biotechnology*, **26**, 2206-2213. https://doi.org/10.4014/jmb.1609.09012

[30] Fakhim, H., Vaezi, A., Dannaoui, E., Chowdhary, A., Nasiry, D., Faeli, L., *et al.* (2018) Comparative Virulence of *Candida auris* with *Candida haemulonii*, *Candida glabrata* and *Candida albicans* in a Murine Model. *Mycoses*, **61**, 377-382. https://doi.org/10.1111/myc.12754

[31] Sarma, S. and Upadhyay, S. (2017) Current Perspective on Emergence, Diagnosis and Drug Resistance in *Candida auris*. *Infection and Drug Resistance*, **10**, 155-165. https://doi.org/10.2147/IDR.S116229

[32] Sharma, C., Kumar, N., Pandey, R., Meis, J.F. and Chowdhary, A. (2016) Whole Genome Sequencing of Emerging Multidrug Resistant *Candida auris* Isolates in India Demonstrates Low Genetic Variation. *New Microbes and New Infections*, **13**, 77-82. https://doi.org/10.1016/j.nmni.2016.07.003

[33] Bassetti, M., Taramasso, L., Nicco, E., Molinari, M.P., Mussap, M. and Viscoli, C. (2011) Epidemiology, Species Distribution, Antifungal Susceptibility and Outcome of Nosocomial Candidemia in a Tertiary Care Hospital in Italy. *PLoS ONE*, **6**, e24198. https://doi.org/10.1371/journal.pone.0024198

[34] Perlin, D.S. (2015) Echinocandin Resistance in *Candida*. *Clinical Infectious Diseases*, **61**, S612-S617. https://doi.org/10.1093/cid/civ791

[35] Bii, C.C., Kangogo, M., Revathi, G. and Wanyoike, W. (2009) Genotypes of *Candida albicans* from clinical sources in Nairobi Kenya. *African Journal of Microbiology*

Research, **3**, 475-477.

[36] Navalkele, B.D., Revankar, S. and Chandrasekar, P. (2017) *Candida auris*: A Worrisome, Globally Emerging Pathogen. *Expert Review of Anti-Infective Therapy*, **15**, 819-827. https://doi.org/10.1080/14787210.2017.1364992

[37] Desnos-Ollivier, M., Bretagne, S., Bernède, C., Robert, V., Raoux, D., Elisabeth, C., Forget, E., Lacroix, C., Dromer, F. and the YEASTS Group (2008) Clonal Population of Flucytosine-Resistant *Candida tropicalis* from Blood Cultures, Paris, France. *Emerging Infectious Diseases*, **14**, 557-565. https://doi.org/10.3201/eid1404.071083

[38] Lotfali, E., Kordbacheh, P., Mirhendi, H., Zaini, F., Ghajari, A., Mohammadi, R., *et al.* (2016) Antifungal Susceptibility Analysis of Clinical Isolates of *Candida parapsilosis* in Iran. *Iranian Journal of Public Health*, **45**, 322-328.

[39] Eksi, F., Gayyurhan, E.D. and Balci, I. (2013) *In Vitro* Susceptibility of *Candida* Species to Four Antifungal Agents Assessed by the Reference Broth Microdilution Method. *The Scientific World Journal*, **2013**, Article ID: 236903. https://doi.org/10.1155/2013/236903

[40] Souza, A.C.R., Fuchs, B.B., Pinhati, H.M.S., Siqueira, R.A., Hagen, F., Meis, J.F., *et al.* (2015) *Candida parapsilosis* Resistance to Fluconazole: Molecular Mechanisms and *In Vivo* Impact in Infected *Galleria mellonella* Larvae. *Antimicrobial Agents and Chemotherapy*, **59**, 6581-6587. https://doi.org/10.1128/AAC.01177-15

[41] Cleveland, A.A., Farley, M.M., Harrison, L.H., Stein, B., Hollick, R., Lockhart, S.R., *et al.* (2012) Changes in Incidence and Antifungal Drug Resistance in Candidemia: Results from Population-Based Laboratory Surveillance in Atlanta and Baltimore, 2008-2011. *Clinical Infectious Diseases*, **55**, 1352-1361. https://doi.org/10.1093/cid/cis697

[42] Mandelblat, M., Frenkel, M., Abbey, D., Ben, R., Berman, J. and Segal, E. (2017) Phenotypic and Genotypic Characteristics of *Candida albicans* Isolates from Bloodstream and Mucosal Infections. *Mycoses*, **60**, 534-545. https://doi.org/10.1111/myc.12623

[43] Ture, Z. and Alp, E. (2018) Infection Control Measures to Prevent Hospital Transmission of *Candida*. *Hospital Practice*, **46**, 253-257. https://doi.org/10.1080/21548331.2018.1510282

[44] Schwartz, I.S., Smith, S.W. and Dingle, T.C. (2018) Something Wicked This Way Comes: What Health Care Providers Need to Know about *Candida auris*. *Canada Communicable Disease Report*, **44**, 271-276. https://doi.org/10.14745/ccdr.v44i11a01

[45] Schelenz, S., Hagen, F., Rhodes, J.L., Abdolrasouli, A., Chowdhary, A., Hall, A., *et al.* (2016) First Hospital Outbreak of the Globally Emerging *Candida auris* in a European Hospital. *Antimicrobial Resistance & Infection Control*, **5**, Article No. 35. https://doi.org/10.1186/s13756-016-0132-5

Abbreviations

CCU: Critical Care Units;

ICU: Intensive Care Unit;

HDU: Highly Dependent Unit;

SDA: Saboraud Dextrose Agar;

JKUAT: Jomo Kenyatta University of Agriculture and Technology.