Infection and Drug Resistance

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ORIGINAL RESEARCH

Clinical Distribution and Drug Susceptibility Characterization of Invasive *Candida* Isolates in a Tertiary Hospital of Xinjiang Province

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Objective: This study aims to investigate the clinical distribution characteristics and drug susceptibility profiles of invasive *Candida* isolates in a tertiary hospital in Urumqi.

Methods: The examination was conducted on samples obtained from patients who were clinically diagnosed with invasive candidiasis in this hospital. A total of 109 strains of *Candida* strains were identified through the use of internal transcribed spacer (ITS) sequencing and fungal cultivation methods.The clinical distribution of the strains was analyzed. Antifungal drug susceptibility tests were performed using the Sensititre YO10 fungal drug susceptibility plate based on the micro-broth dilution method.

Results: *Candida albicans* had the highest percentage (51.38%) among 109 *Candida* isolates, followed by *C. glabrata* (18.35%) and *C. tropicalis* (15.60%). The isolates were predominantly found in the respiratory department (41.28%), intensive care unit (ICU) (31.19%), and infection department (9.17%).The results of drug susceptibility tests indicated that amphotericin B, 5-fluorocytosine, and echinocandins exhibited good in vitro antifungal activity, with a susceptibility rate of over 96%. However, the azoles demonstrated low antifungal activity, especially posaconazole and voriconazole, which had high resistance rates of 64.71% for *C. tropicalis* and 70% for *C. glabrata*, respectively.

Conclusion: In our hospital, *Candida albicans* was identified as the primary causal agent of invasive candidiasis. In terms of in vitro antifungal activity, echinocandins, amphotericin B, and 5-fluorocytosine demonstrated efficacy against invasive *Candida* infections. However, it was important to note that *C. glabrata* and *C. tropicalis* exhibited low susceptibility to azoles.

Keywords: *Candida* isolates, clinical distribution, antifungal drug susceptibility tests, drug resistance

Introduction

The incidence of invasive fungal infections is increasing, attributed to the wide usage of glucocorticoids, broad-spectrum antibiotics, immunosuppressants, as well as advances in invasive manipulation techniques and novel therapeutic approaches.[1,2] Among these infections, invasive candidiasis is the most common, with *Candida albicans* being the predominant causative agent; however, due to the widespread use of antifungal medications, there is an epidemiological shift in the prevalence of strains from *Candida albicans* to non-*Candida albicans Candida species* (NCAC).[3] The epidemiology and drug sensitivity of invasive *Candida* strains vary based on different regions, patients, and doctors' medication practices. Understanding the local distribution of strains and their drug susceptibility brings numerous advantages in terms of prompt detection and therapy, thereby improving the cure rate and reducing drug resistance and adverse reactions caused by long-term empiric and preventive use of antifungal drugs.

This research aimed to analyze the distribution of *Candida* strains obtained from patients with invasive candidiasis within a prominent tertiary care hospital situated in Urumqi, the capital city of Xinjiang Province. Furthermore, we evaluated the

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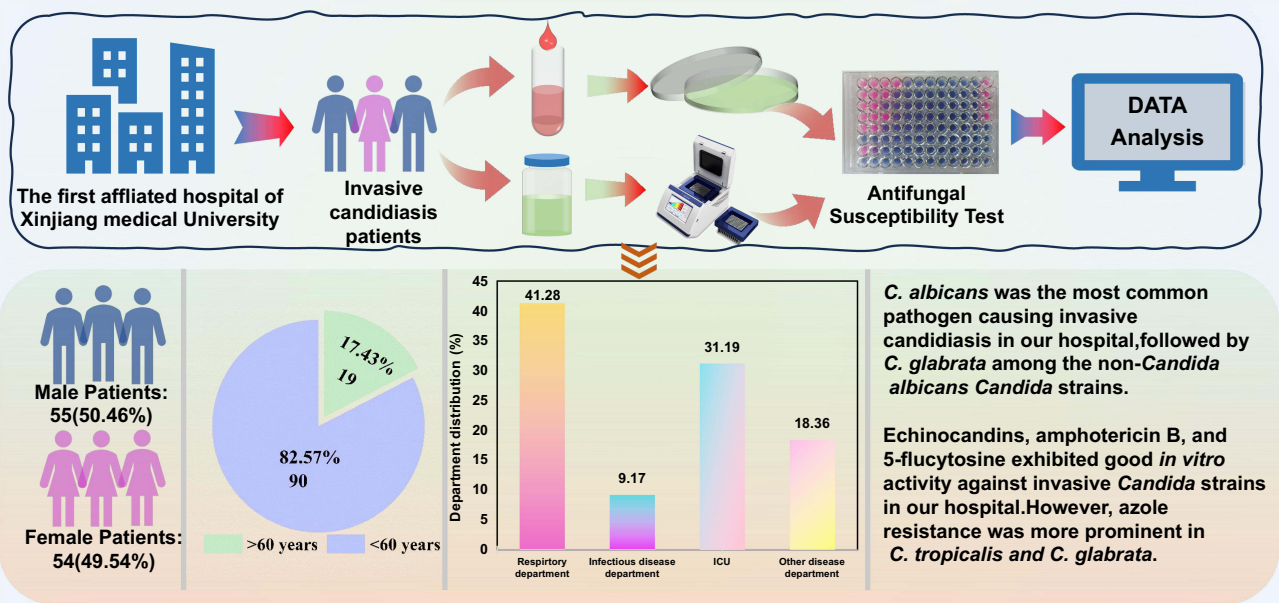
Graphical Abstract



characteristics of drug resistance to establish a credible scientific foundation for improving the diagnosis and treatment strategies for invasive *Candida* infections in the local area.

Material and Methods

Fungal Isolates Collection and Identification

Samples were obtained from the respiratory tract, digestive tract and other parts of patients who were clinically diagnosed with invasive candidiasis in all the wards in the First Affiliated Hospital of Xinjiang Medical University from June 2022 to June 2023. A total of 109 *Candida* strains were detected, ensuring that any replication of strains from a single patient was excluded. The identification of strains involved the use of *Candida* chromogenic media (CHROMagar, France) for morphological identification and ITS sequencing for molecular biological identification.DNA samples from *Candida* strains were PCR amplified using fungal universal primers ITS1/ITS4.ITS 1:5'-TCCGTAGGTGAACCTGCGG-3', ITS4:5'-TCCTCCGCTTATTGATATGC-3'.PCR programme included: 94°C (5 min); 94° C (30 sec); 55°C(30 sec) and 72°C (90 sec) for 35 cycles; and then a final extension of 72°C (8 min).The obtained sequences were aligned with the corresponding sequences of reference *Candida* strains in GenBank. GenBank accession numbers of ITS1/ITS4 sequences are listed in Supplementary Table 1.

Antifungal Susceptibility Tests

The in vitro drug susceptibility test was conducted according to the Sensititre Yeast One YO10 product specification. The minimal inhibitory concentration (MIC) of amphotericin B, 5-fluorocytosine, anidulafungin, caspofungin, micafungin, fluconazole, itraconazole, posaconazole, and voriconazole was determined using Sensitizer YO10 fungal sensitization plates (Thermo Fisher Scientific, USA) based on the micro bouillon dilution method. MIC results for *Candida* isolates were read after 24 hours of culture, with the positive control well serving as the reference. The drug susceptibility results of different strains were interpreted based on the latest M60-Ed2 document[4] of the Clinical and Laboratory Standards Institute (CLSI) for clinical breakpoints (CBPs). For strains without clinical breakpoints, the epidemiological cutoff values (ECVs) of CLSI M59-Ed3[5] were used for interpretation. The quality control strains used were *C. parapsilosis* ATCC22019 and *C. Krusei* ATCC6258. Measured ITS sequences were compared using mafft software[6], and the

phylogenetic tree was constructed through Fast Tree software[7] using the maximum likelihood method along with 1000 bootstrap tests. The drug resistance index (log (Drug Concentration)) was calculated using the logarithm of the MIC value obtained from the drug susceptibility test. The drug resistance index was then represented as a heat map on the periphery of the phylogenetic tree. Visualization was performed using the online tool iTol.[8]

Statistical Analysis

All data analyses and graphs were performed using SPSS (version 22, Chicago, USA) and Origin (version 2018, Northampton, USA) software. Count data were presented as frequencies or constituent ratios. A P value < 0.05 was considered statistically significant for all statistical analyses.

Results

Clinical Distribution Characteristics of Candida Isolates

A total of 109 *Candida* isolates were obtained from the samples sent for analysis. The isolates were incubated in *Candida* chromogenic medium and identified by sequencing the ITS region (Figure 1). The total 109 isolates that were examined, 55 (50.46%) were obtained from male patients while the remaining 54 (49.54%) were obtained from female patients. The patients ranged in age from 25 to 93 years, with a mean age of 74 (65,81) years. Among the isolates, 90 were from patients over 60 years of age, while 19 were from patients under 60 years of age. In terms of department distribution, 45 (41.28%) isolates were obtained from the respiratory department, 34 (31.19%) were from the intensive care unit (ICU), and 10 (9.17%) were from the infectious diseases department (Figure 2).

Distribution of Candida Isolates

A total of seven *Candida* species were identified among the 109 *Candida* strains. *Candida albicans* was found to be the most prevalent species, accounting for 51.38% (56/109) of the strains. Non-*Candida albicans Candida* (NCAC) species accounted for 48.62% of the strains, with *C. glabrata* being the most dominant at 18.35% (20/109), followed by *C. tropicalis* at 15.60% (17/109), and *C. krusei* at 7.34% (8/109). *Candida* isolates were obtained from various parts

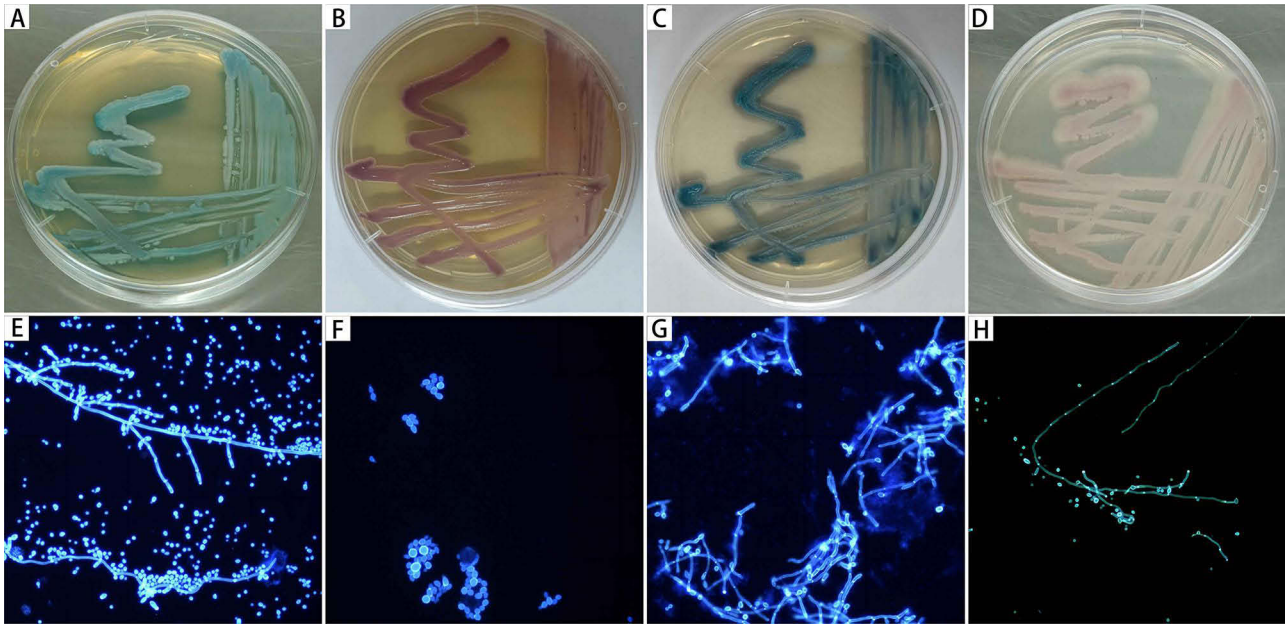


Figure 1 Identification of the *Candida* isolates (**A**–**D**) are colony morphology of *Candida albicans, Candida glabrata, Candida tropicalis and Candida krusei* on chromogenic medium (CHROMagar),respectively; (**E**–**H**) are morphology of *Candida albicans,Candida glabrata, Candida tropicalis and Candida krusei* calcofluor white staining under microscope, respectively (×400).

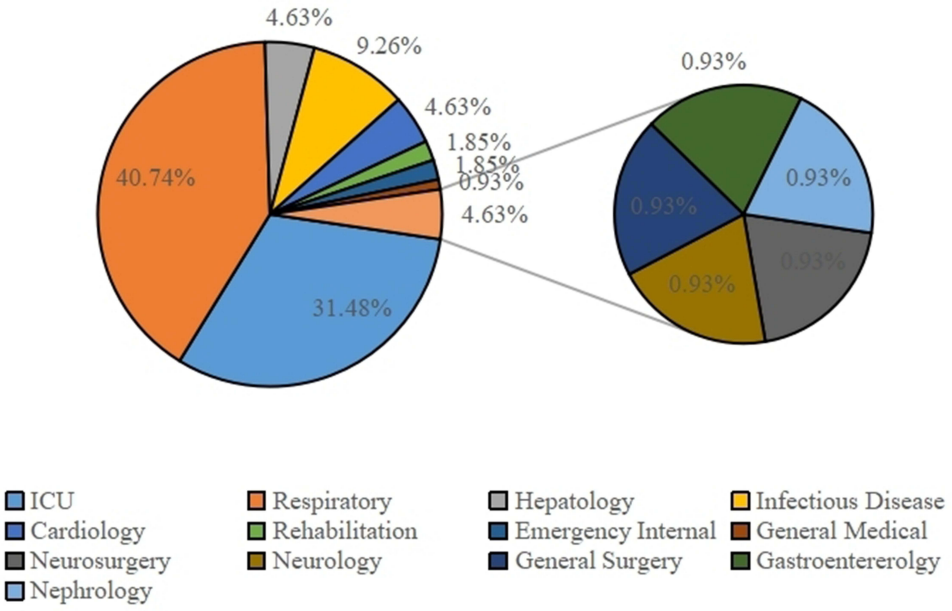


Figure 2 Distribution of *Candida* isolates in the clinical department.

of the respiratory tract, urinary tract, gastrointestinal tract, and others. The majority of isolates (77.98%, 85/109) were from sputum, followed by urine (15.60%, 17/109), and bronchoalveolar lavage fluid (BALF)(3.67%, 4/109) (Table 1).

In vitro Antifungal Susceptibility Profiles

In this study, we analyzed the drug susceptibility profiles of *Candida* species with interpretive standards (CBPs or ECVs) to nine antifungal drugs commonly used in clinical settings. For the sake of simplicity, we refer to phenotypic strains that were susceptible (S) and wild-type (WT) as ”susceptible strains”, while resistant strains (R)and non-wild-type (NWT) were referred to as ”resistant strains”.

In vitro Antifungal Susceptibility to Azoles

A total of 3.57% (2/56), 7.14% (4/56) 7.14% (4/56) and 10.71% (6/56) of *Candida albicans* showed resistance to voriconazole (VOR), Fluconazole (FLC), itraconazole (ITC), and Posaconazole (POS), respectively. Compared to *C. albicans*, NCAC species exhibited variable levels of resistance. Only 35.29% (6/17) of *Candida tropicalis* were

Table 1 Specimen Distribution of *Candida* Isolates [*n*(%)]

Species	Sputum		Urine		Feces		Throat swab		BALF		Total	
	n	Proportion (%)	n	Proportion (%)	n	Proportion (%)	n	Proportion (%)	n	Proportion (%)	n	Proportion (%)
C. albicans	49	56.32	5	29.41	0	0	1	100	1	25.00	56	51.38
C. Glabrata	16	18.39	3	17.65	0	0	0	0	1	25.00	20	18.35
C. tropicalis	12	13.79	3	17.65	1	50.00	0	0	1	25.00	17	15.60
C. krusei	4	4.60	3	17.65	1	50.00	0	0	0	0	8	7.34
C. lusitaniae	2	2.30	1	5.88	0	0	0	0	1	25.00	4	3.67
C. parapsilosis	1	1.15	2	11.76	0	0	0	0	0	0	3	2.75
C. kefyr	1	1.15	0	0	0	0	0	0	0	0	1	0.92

susceptible to all azoles, while 64.71% (11/17), 23.53% (4/17), 17.65% (3/17), and 11.76% (2/17) strains demonstrated resistance to POS, FLC, VOR and ITC, respectively. Within the *C. glabrata* isolates, one strain showed resistance to FLC, whereas the other 19 strains showed a susceptible dose-dependent phenotype (SDD). Furthermore, 70% (14/20), 45% (9/20), and 5% (1/20) of *C. glabrata* isolates showed resistance to VOR, POS, and ITC, respectively. One isolate of *C. krusei* exhibited cross-resistance to all three azoles, while one *C. parapsilosis* demonstrated resistance to 5-Flucytosine (5-FC) and FLC. Both isolates of *C. lusitania* were sensitive to all azoles (Table 2).

In vitro Antifungal Susceptibility to Echinocandins, AMB, and 5-FC

Most of the *Candida* isolates in this study were highly susceptible to echinocandins, with an overall susceptibility rate of over 95%. No echinocandin-resistant strains were found, particularly in *C. albicans, C. tropicalis, C. krusei, C. parapsilosis, and C. lusitaniae*. Only two *C. glabrata* strains demonstrated resistance to echinocandins, one of which was resistant to CAS and the other was cross-resistant to Anidulafungin (AND),Micafungin (MCF), and Caspofungin (CAS).In this study, Amphotericin B (AmB) and 5-Flucytosine (5-FC) displayed good in vitro antifungal activity against most of the *Candida* species, with a susceptibility rate of over 99%. (Table 2).

Table 2 In vitro Antifungal Susceptibility Profiles

Species, Antifungal agent	MIC/ (mg/L)			Drug sensitivity results (%)					
	GM	MIC_{50}	MIC_{90}	S	I	SDD	R	WT	NWT
C. albicans, n=56									
AND	0.038	0.030	0.060	100	0	—	0	—	—
MCF	0.011	0.015	0.015	100	0	—	0	—	—
CAS	0.039	0.030	0.060	100	0	—	0	—	—
POS	0.040	0.030	0.120	—	—	—	—	89.29	10.71
VOR	0.015	0.008	0.030	92.86	3.57	—	3.57	—	—
ITZ	0.082	0.060	0.120	—	—	—	—	92.86	7.14
FLC	0.428	0.250	1.000	92.86	—	0	7.14	—	—
5-Fc	0.083	0.060	0.250	—	—	—	—	100	0
AmB	0.724	1.000	1.000	—	—	—	—	100	0
C. glabrata, n=20									
AND	0.037	0.015	0.030	90	5	—	5	—	—
MCF	0.024	0.015	0.030	90	5	—	5	—	—
CAS	0.077	0.060	0.250	85	5	—	10	—	—
POS	1.741	2.000	2.000	—	—	—	—	55	45
VOR	0.555	0.500	1.000	—	—	—	—	30	70
ITZ	0.841	1.000	1.000	—	—	—	—	95	5
FLC	18.379	16.000	32.000	—	—	95	5	—	—
5-Fc	0.079	0.060	0.060	—	—	—	—	95	5
AmB	0.933	1.000	1.000	—	—	—	—	100	0

(*Continued*)

Table 2 (Continued).

Species, Antifungal agent	MIC/ (mg/L)			Drug sensitivity results (%)					
	GM	MIC_{50}	MIC_{90}	S	I	SDD	R	WT	NWT
C. tropicalis, n=17									
AND	0.022	0.015	0.060	100	0	—	0	—	—
MCF	0.023	0.030	0.030	100	0	—	0	—	—
CAS	0.417	0.030	0.120	94.12	5.88	—	0	—	—
POS	0.303	0.500	1.000	—	—	—	—	35.29	64.71
VOR	0.158	0.250	1.000	35.29	47.06	—	17.65	—	—
ITZ	0.316	0.250	1.000	—	—	—	—	88.24	11.76
FLC	2.000	2.000	16.000	64.71	—	11.76	23.53	—	—
5-Fc	0.084	0.060	0.250	—	—	—	—	100	0
AmB	0.922	1.000	2.000	—	—	—	—	94.12	5.88
C. krusei, n=8									
AND	0.042	0.030	0.120	100	0	—	0	—	—
MCF	0.146	0.250	0.250	100	0	—	0	—	—
CAS	0.122	0.120	0.250	100	0	—	0	—	—
POS	0.384	0.500	8.000	—	—	—	—	87.50	12.50
VOR	0.298	0.250	8.000	87.5	0	—	12.5	—	—
ITZ	0.384	0.250	16.000	—	—	—	—	87.50	12.50
FLC	24.675	32.000	128.000	IR	IR	IR	IR	IR	IR
5-Fc	1.393	8.000	8.000	—	—	—	—	100	0
AmB	0.917	1.000	2.000	—	—	—	—	100	0
C. lusitaniae, n=4									
AND	0.120	0.120	0.120	—	—	—	—	100	0
MCF	0.120	0.120	0.120	—	—	—	—	100	0
CAS	0.247	0.250	0.500	—	—	—	—	100	0
POS	0.030	0.030	0.030	—	—	—	—	100	0
VOR	0.009	0.008	0.015	—	—	—	—	100	0
ITZ	0.071	0.060	0.120	—	—	—	—	100	0
FLC	0.595	0.500	1.000	—	—	—	—	100	0
5-Fc	0.060	0.060	0.060	—	—	—	—	100	0
AmB	0.707	0.500	1.000	—	—	—	—	100	0

(*Continued*)

Table 2 (Continued).

Species, Antifungal agent	MIC/ (mg/L)			Drug sensitivity results (%)					
	GM	MIC_{50}	MIC_{90}	S	I	SDD	R	WT	NWT
C. parapsilosis, n=3									
AND	1.259	2.000	2.000	100	0	—	0	—	—
MCF	1.587	2.000	2.000	100	0	—	0	—	—
CAS	0.500	0.500	1.000	100	0	—	0	—	—
POS	0.531	0.030	0.250	—	—	—	—	100	0
VOR	0.318	0.008	0.500	66.7	33.3	—	0	—	—
ITZ	0.048	0.030	0.120	—	—	—	—	100	0
FLC	1.587	0.500	32.000	66.67	—	33.33	0	—	—
5-Fc	0.243	0.060	4.000	—	—	—	—	100	0
AmB	0.500	0.500	1.000	—	—	—	—	100	0

Abbreviations: AND Anidulafungin; MCF, Micafungin; CAS, Caspofungin; POS, Posaconazole; VOR, voriconazole; ITZ, Itraconazole; FLC, Fluconazole; 5-Fc, 5-Flucytosine; AmB, Amphotericin B.

Multiple Drug Resistance and Cross-Drug Resistance of Candida Isolates

Multi-resistant strains are defined as strains that are not susceptible to at least 2 categories of antifungal drugs, while cross-resistant strains are strains that are not susceptible to at least 2 drugs in the same category of antifungal drugs.[9] In this study, we identified a total of four isolates of *C. albicans* cross resistant to azoles. Out of these, two isolates exhibited cross resistance to POS, ITC, and FLC, whereas the other two were resistant to all four azoles. Additionally, we discovered five strains of *C. tropicalis* resistant to azoles. One isolate displayed cross-resistant to POS and VOR, while two isolates were cross-resistant to POS and FLC, and the other two isolates were resistant to all four azoles. Among these, one isolate was a resistant strain that was resistant to all azoles and AmB. Furthermore, we observed nine azoles cross-resistant strains of *C. glabrata*. Eight of these strains were cross-resistant to POS and VOR, and one strain was resistant to all four azoles. Additionally, we identified two multi-resistant strains of *C. glabrata*. One strain was resistant to VOR and 5-FC, while the other strain was resistant to POS, VOR, and CAS. Interestingly, one isolate of *C. glabrata* was found to be resistant to all three echinocandins simultaneously. We also discovered that isolate of *C. krusei* exhibited cross-resistance to POS, VOR, and ITC. Lastly, one isolate of *C. parapsilosis* was identified as a multi-resistant strain resistant to 5-FC and FLC (Tables 3 and 4).

Table 3 Multi-Drug Resistance and Cross-Resistance of *Candida* Strains

Species	Multi-drug resistance and cross-resistance of *Candida* species (n)				
	Azoles cross-resistance	Azoles and 5-FC	Azoles and AmB	Azoles and echinocandins	Echinocandins cross-resistance
C. albicans	4	0	0	0	0
C. tropicalis	5	0	1	0	0
C. glabrata	9	1	0	1	1
C. krusei	1	0	0	0	0
C. parapsilosis	0	1	0	0	0

Table 4 Azoles Cross-Resistance of *Candida* Strains

Species	Azoles cross-resistance strains (n)				
	POS ITZ FLC VOR	POS ITZ FLC	POS ITZ VOR	POS FLC	POS VOR
C. albicans	2	2	0	0	0
C. tropicalis	2	0	0	2	1
C. glabrata	1	0	0	0	8
C. krusei	0	0	1	0	0
C. parapsilosis	0	0	0	0	0

Phylogenetic Tree and Heat Map of Drug Resistance Levels Constructed Based on ITS Sequences

The heat map displayed drug susceptibility for different *Candida* strains to antifungal drugs.The outermost circles indicated strain numbers, with each column representing a strain and each row representing an antifungal agent.The heat map values indicated the drug resistance index, which was calculated as the logarithm of the MIC value obtained from drug susceptibility testing.The color from blue to red indicated the log (MIC) value from large to small, and the more obvious the blue-red color contrast indicated the greater the difference in the minimum inhibitory concentration of the drug. In the picture, the color of the azoles area was closer to blue and the echinocandins was closer to red.The heat map of resistance index showed that *Candida* isolates were more sensitive to echinocandins and had a more obvious resistance trend to azoles (Figure 3).

Discussion

The incidence of invasive candidiasis is increasing worldwide, largely due to the continuous development of contemporary medicine and nosocomial infections.[10] This is further exacerbated by the growing resistance of *Candida* species, which is the result of the widespread empirical and prophylactic use of antifungal drugs. In particular, the emergence of multidrug-resistant species like *Candida auris*[11] and *Candida vulturna*[12] has posed a significant challenge to clinical treatment. Hence, it is crucial to understand the regional prevalence of invasive *Candida* strains and their susceptibility to antifungal drugs. Acquiring these information will greatly contribute to the prevention, control, and management of invasive candidiasis.

The findings of this research demonstrated that the invasive *Candida* species were distributed primarily in the respiratory department, ICU, hepatology department, and other departments, with a high prevalence among patients over 60 years of age. This correlation could potentially be attributed to the severe illness of patients in these departments, the administration of broad-spectrum antibiotics and glucocorticoids, and the frequent utilization of invasive procedures and medical equipment. The increased susceptibility of elderly patients may be linked to age-related physiological changes, multiple underlying diseases, and the complexity of medication use.[13] Previous studies[14] have indicated that more than 90% of invasive *Candida* species comprise *C. albicans, C. glabrata, C. tropicalis, C. krusei* and *C. parapsilosis*, with *C. albicans* being the most commonly identified pathogenic species. In recent times, the proportion of NCAC species has increased significantly, even exceeding the proportion of *C. albicans* in some areas.[15,16] A global SENTRY antifungal surveillance program[17] revealed that *C. albicans* accounted for the highest number of isolates in all monitoring regions from 1997 to 2016. Additionally, *C. glabrata* was the most common NCAC species in the Asia-Pacific, Europe, and North America, while Latin America frequently reported *C. parapsilosis* and *C. tropicalis*. The most prevalent NCAC species in *Canada* was found to be *C. glabrata*, according to a multi-center study.[18] Similarly, another SENTRY antifungal surveillance program[19] identified *C. glabrata* as the most common NCAC species in patients over 65 years of age with invasive candidiasis. However, in some large-sample, multi-center studies in China, *C. parapsilosis* was found to be the most frequently isolated NCAC strain.[20,21] Within the scope of this study, *C. albicans* constituted the most frequently isolated pathogen, followed by *C. glabrata, C. tropicalis*, and *C. krusei*. Some multi-center studies of Urumqi reported by Yi[22] and Abibai[23] found that the most common *Candida* species of invasive candidiasis were

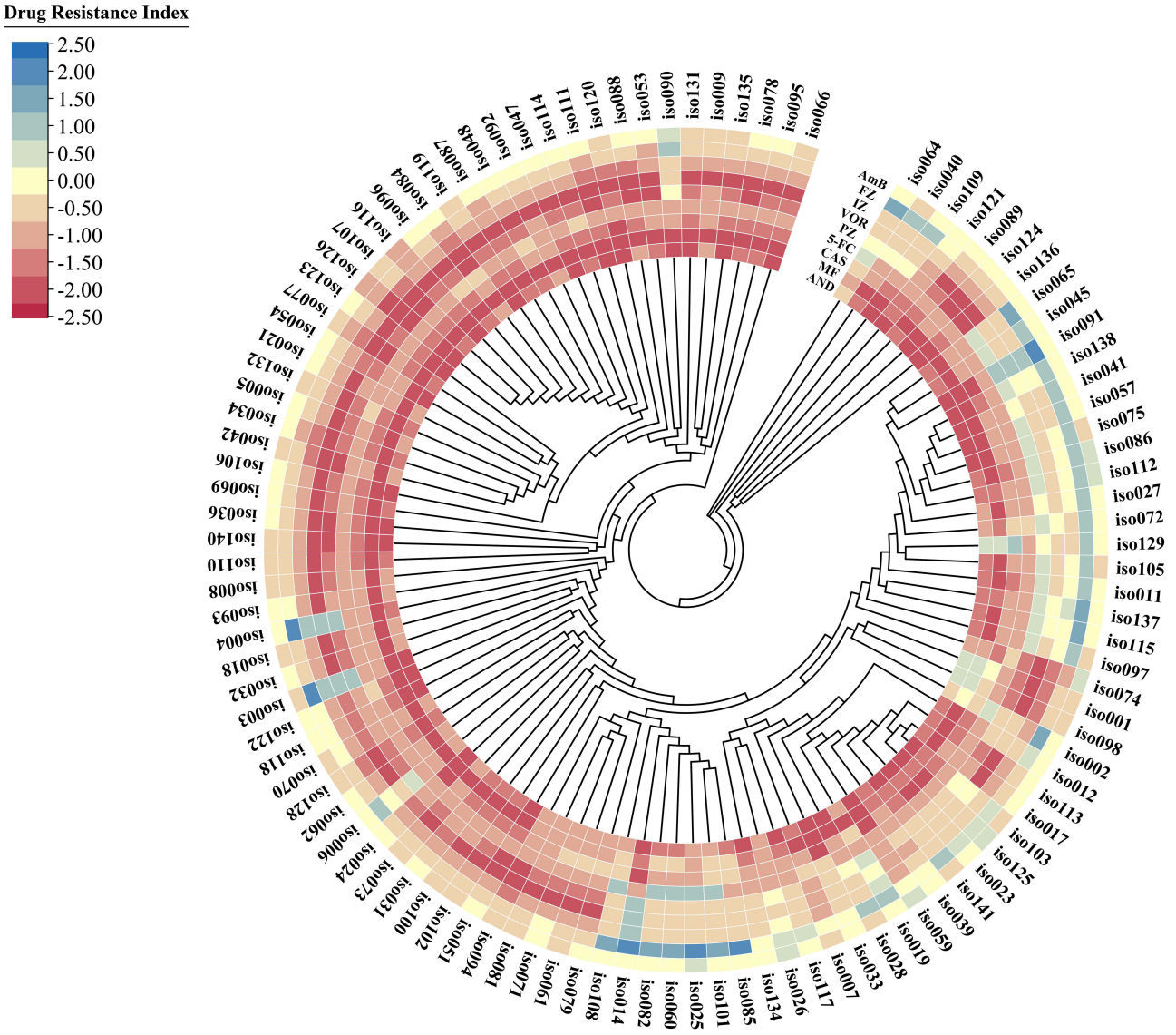


Figure 3 Phylogenetic tree and heat map of drug resistance levels constructed based on ITS sequences. The heat map shows the drug resistance index for different strains of antifungal drugs. The outermost circle shows the strain number, with each column representing a strain, and each row representing an antifungal drug. The heat map values indicate the drug resistance index, which is calculated as the logarithm of the MIC value obtained from drug susceptibility testing.
Abbreviations: AND, Anidulafungin; MCF, Micafungin; CAS, Caspofungin; POS, Posaconazole; VOR, Voriconazole; IZ, Itraconazole; FZ, Fluconazole; 5-Fc, 5-Flucytosine, AmB, Amphotericin.

C. tropicalis and *C. parapsilosis*,respectively. Similarly, a study conducted in a tertiary hospital in Anhui province and reported by Xia[24] identified *C. glabrata* as the most common isolates in invasive candidiasis. These findings indicated that the epidemiologic distribution of invasive *Candida* strains varied by region and time and was influenced by factors such as the source of the sample, the affected population, and the use of medications. Therefore, it is crucial to actively monitor the epidemiology of invasive *Candida* strains in local areas.

In our research, the majority of *Candida* strains showed high sensitivity to AmB and 5-FC, with a sensitivity rate of over 99%. There was only one isolate of *C. tropicalis* that demonstrated NWT to AMB, and one isolate of *C. glabrata* that showed NWT to 5-FC. This suggests that these drugs may help treat invasive candidiasis invasive candidiasis in our hospital. Regarding C. *albicans* strains, they were relatively sensitive to azoles; however, the resistance rate to FLC was higher compared to global data[17] and the average rate in our country[21] (7.1% vs 0.3% and 4.1%, respectively). This could be attributed to the relatively high usage of FLC in our institution. Previous studies[25,26] have found that NCAC species, such as *C. glabrata* and *C. tropicalis*, naturally exhibit lower sensitivity to azoles. Some researchers[20,21,27] have summarized the drug susceptibility of *Candida* strains

in mainland China over 10 years from 2011 to 2021. They discovered that the resistance rate of *C. glabrata* and *C. tropicalis* to FLC exceeded 20%, particularly for *C. tropicalis*, which showed an increase in resistance rate from less than 6% to over 30% between 2015 and 2017. The susceptibility rate of *C. tropicalis* to voriconazole and posaconazole in our study was only 35.29%, which was lower than that reported in Guangdong[28] and Sichuan Province[29] in the same period.Similar to reports from Beijing,[15] our study revealed that *C. glabrata* had the highest rate of resistance to VOR, with 70.5% and 45% of *C. glabrata* isolates being resistant to VOR and POS respectively. Azole resistance in *C. glabrata* is more common in Xinjiang than in Anhui[30] and Hebei[31] Province.Therefore, it is essential to carefully consider the selection of POS and VRC for the treatment of *C. glabrata* and *C. tropicalis* infections in our hospital. The overall resistance rate of *Candida* strains to POS and VOR was high in this study (25% and 18.5% respectively). Notably, among the 27 strains (27/109, 24.8%) that were not susceptible to POS, 19 strains (19/27, 70.4%) exhibited cross-resistance to other azoles. This highlights the need to be cautious about the potential cross-resistance to other drugs when choosing POS for treatment.

In this study, only two isolates of *C. glabrata* were found to be resistant to echinocandins, which is consistent with the findings of Song[15] and Xiao.[20] *C. glabrata* is considered to be the most frequently resistant species to echinocandins, as reported by Alexander.[32] Our study revealed that the overall resistance rate of *Candida* strains to echinocandins was less than 2%. Based on the recommendations of existing guidelines[33,34] and considering the drug susceptibility of our hospital, echinocandins can be considered as the preferred first-line therapeutic agents for invasive candidiasis in our hospital. In addition, it is noteworthy that we identified four multidrug-resistant *Candida* isolates. Given the limited availability of antifungal agents for patients infected with these multidrug-resistant strains, it is vital to improve the management of antifungal drug usage and monitor resistance to minimize the emergence and spread of multidrug-resistant strains caused by the inappropriate use of antifungal drugs.

The limitation of this research is that it is a single-center study, which may not be representative of the patients in the general population. To enhance the comprehensiveness of future research, we will further include samples from multiple centers and investigate the resistance mechanisms of drug-resistant *candida* strains. Furthermore, incorporating clinical information about patients, including risk factors, baseline conditions, previous medication, prognosis and outcome, would provide a more detailed scientific foundation for the diagnosis and treatment of invasive candidiasis in Xinjiang region of China. In conclusion, the departments with high incidence of invasive *Candida* infections were the respiratory department, ICU, and hepatology department. *C. albicans* was found to be the most common pathogen causing invasive candidiasis in our hospital, followed by *C. glabrata* in the NCAC strains Echinocandins, amphotericin B, and 5-flucytosine have good in vitro activity against invasive *Candida* strains in our hospital. However, azoles resistance is more prominent in *C. tropicalis* and *C. glabrata*. It is important to note that our hospital has identified multidrug-resistant strains that are resistant to two classes of antifungal drugs. Clinicians should highly prioritize these findings and implement timely, dynamic, and continuous drug susceptibility monitoring as well as standardized antifungal treatment. Although this study was conducted in a single-center setting, it is important to note that our hospital is the largest tertiary care hospital in the Xinjiang region. Therefore, we believe that these data can provide meaningful clinical basis for the prevention and management of invasive candidiasis.

Ethics Statement

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval for the study was obtained from the Ethics Committee of the First Affiliated Hospital of Xinjiang Medical University. All patients consented to being involved in this study. (Approval number: K202305-04).

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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