

First report on echinocandin resistant Polish *Candida* isolates

Martyna Mroczyńska and Anna Brillowska-Dąbrowska✉

Gdańsk University of Technology, Faculty of Chemistry, Department of Molecular Biotechnology and Microbiology, Gdańsk, Poland

Purpose: *Candida* spp. are ranked as one of the four major causative agents of fungal infections. The number of infections caused by *Candida* species resistant to fluconazole, which is applied as the first line drug in candidiasis treatment, increases every year. In such cases the application of echinocandin is necessary. Echinocandin susceptibility testing has become a routine laboratory practice in many countries due to the increasing frequency of clinical failures during treatment with these drugs. **Methods:** We performed anidulafungin, micafungin and caspofungin susceptibility testing according to the microdilution broth method on 240 *Candida* isolates collected in Polish hospitals. **Results:** We identified 12 isolates resistant to all echinocandins within 240 examined isolates. Moreover, 6 of the examined samples were identified as rare *Candida* species and among them we observed very high echinocandin MIC values. **Conclusion:** Our research proves that in Poland there is a problem of echinocandin resistance. Moreover, we identified two species of *Candida* which are rare causative agents of human infections, and there was no reported incidence of such infections in Poland until now.

Key words: *Candida* infections, echinocandin resistance, minimal inhibitory concentration, *C. palmiroleophila*, *C. inconspicua*

Received: 31 May, 2019; revised: 16 August, 2019; accepted: 22 August, 2019; available on-line: 12 September, 2019

✉e-mail: annbrill@pg.edu.pl

Abbreviations: AND, anidulafungin; *C.*, *Candida*; CLSI, Clinical and Laboratory Standards Institute procedure; CSP, caspofungin, GRASO, CHROMagar *Candida*; ITS, Internal Transcribed Spacer; MCF, micafungin; MIC, Minimal Inhibitory Concentration

INTRODUCTION

Candida spp. are ranked as the fourth leading causative agent of fungal infections in intensive care units (Sanguinetti *et al.*, 2015). About 90% of these infections are caused by *Candida* (*C.*) *albicans*, *C. glabrata*, *C. parapsilosis*, *C. tropicalis*, and *C. kerusei* (Sanguinetti *et al.*, 2015). So far, the most prevalent pathogen during candidaemia that was isolated has been *C. albicans*. According to the clinical practice guidelines, fluconazole and echinocandin are the first line drugs in empiric therapy in case of *Candida* infections (Pappas *et al.*, 2015). The echinocandin group consists of three compounds: anidulafungin (AND), caspofungin (CSP) and micafungin (MCF). The choice of the appropriate antimycotics is related to the patient's condition, as well as the type of infection. However, an increase in the number of fungal infections caused by non-*albicans* species, such as *C. glabrata* or *C. kerusei*, showing natural resistance to fluconazole (Choi *et al.*, 2009), is the reason for the application of echinocandins. Infections caused by *C. glabrata* are now

the second most common cause of candidaemia in North America and Europe (Pappas *et al.*, 2015), and result in increased mortality rates in patients with candidaemia (Cornely *et al.*, 2014). The frequency of echinocandin resistance among *Candida* spp. differs depending on the species, the region of infection and the patient (Grossman *et al.*, 2014). Studies conducted in different countries have shown a variety of *C. albicans* resistant to echinocandin. According to Castanheira *et al.*'s research, echinocandin resistance among *C. albicans* is at approximately 3% (Castanheira *et al.*, 2010). However, echinocandin resistance among *C. glabrata* seems to be a serious problem. Studies conducted from 2001 to 2010 had shown an increase in resistance from 2-3% to more than 13% among the *C. glabrata* strains (Perlin, 2015).

A report from 2015 made in Italy in accordance with the Clinical and Laboratory Standards Institute procedure (CLSI) has shown the resistance to AND (2.7%), CSP (16.2%) and MCF (13.5%) among *C. glabrata* isolates (Montagna *et al.*, 2015). So far, there has been no information about clinical isolates being resistant to echinocandin in Poland. The frequency of non-*albicans* infections in Poland is increasing. The mortality of patients with candidiasis was 8.5%, in 118 clinical cases of infections in Polish hospitals (Dzierzanowska-Fangrat *et al.*, 2014). Research conducted in 2013 at 20 Polish hospitals based on a two years period, reported 302 cases of candidaemia. The highest number of infections was found in intensive care (30.8%) and surgical (29.5%) units, whereas hematological units reached 15.9%, and the lowest number of infections was seen in neonatological units (4.6%). The most frequent isolated species was *C. albicans* (50.96%). The frequency of *C. kerusei* and *C. tropicalis* was at 24% and 18%, respectively, in the hematology units. The distribution of *C. glabrata* and *C. parapsilosis* was at 14.1% and 13.1%, and there was no statistically significant differences between the departments (Nawrot *et al.*, 2013). The results, published in 2008, 2012, 2014 and 2017, had shown that according to the results of E-tests there were no any non-*Candida* isolates resistant to caspofungin and micafungin (Szymankiewicz & Dancewicz, 2008; Wiczorek *et al.*, 2008; Kurnatowska *et al.*, 2012; Golaś *et al.*, 2014; Sulik-Tysza *et al.*, 2017).

MATERIALS

In this study we identified and examined AND, CSP and MCF susceptibility of 240 *Candida* isolates, collected in four Polish hospitals in Gdansk, Szczecin, Warsaw and Wroclaw, between the years of 2008 to 2012. The isolates originated from a variety of clinical specimens, for example isolated from swabs of the mouth, throat, faeces, urine, blood, and bronchopulmonary lavage fluid.

Table 1. *In vitro* echinocandin susceptibility test results of 240 isolates of *Candida* spp.

Cumulative no. of isolates susceptible at a MIC [mg/l] of:														
MIC breakpoint ¹⁸ [mg/l]				137 isolates of <i>C. albicans</i>										
	S	I	R	≤0.008	0.016	0.031	0.063	0.125	0.25	0.5	1	2	≥4	
AND	≤0.25	0.5	≥1	79	23	14	11	4	1	2	3	-	-	
MCF	≤0.25	0.5	≥1	28	69	22	9	3	-	3	3	-	-	
CSP	≤0.25	0.5	≥1	2	24	34	28	33	7	3	5	-	1	
MIC breakpoint ¹⁸ [mg/l]				72 isolates of <i>C. glabrata</i>										
	S	I	R	≤0.008	0.016	0.031	0.063	0.125	0.25	0.5	1	2	≥4	
AND	≤0.12	0.25	≥0.5	3	10	32	13	5	-	4	4	1	-	
MCF	≤0.12	0.25	≥0.5	7	31	19	3	3	1	-	7	1	-	
CSP	≤0.06	0.12	≥0.25	-	2	7	22	22	10	2	5	-	2	
MIC breakpoint ¹⁸ [mg/l]				17 isolates of <i>C. krusei</i>										
	S	I	R	≤0.008	0.016	0.031	0.063	0.125	0.25	0.5	1	2	≥4	
AND	≤0.25	0.5	≥1	-	2	3	11	-	-	-	-	-	1	
MCF	≤0.25	0.5	≥1	-	1	-	-	12	3	-	-	-	1	
CSP	≤0.25	0.5	≥1	-	-	-	-	-	1	2	13	-	1	
MIC breakpoint ¹⁸ [mg/l]				8 isolates of <i>C. parapsilosis</i>										
	S	I	R	≤0.008	0.016	0.031	0.063	0.125	0.25	0.5	1	2	4	8
AND	≤2	4	≥8	-	-	-	-	1	-	2	4	-	-	1
MCF	≤2	4	≥8	-	-	-	-	1	-	-	6	-	-	1
CSP	≤2	4	≥8	-	-	-	-	1	-	2	1	1	2	1
				6 other isolates (5 <i>C. palmiophila</i> and 1 <i>C. inconspicua</i>)										
				0.008	0.016	0.031	0.063	0.125	0.25	0.5	1	2	≥4	
Lack of MIC breakpoint				2	-	-	-	-	-	2	-	-	2	
				2	-	-	-	-	-	1	1	-	2	
				-	2	-	-	-	-	-	1	-	3	

METHODS

All isolates were cultured on CHROMagar Candida (GRASO) medium and incubated for 48 h at 35°C. For the species identification, ITS1, 5.8S RNA, ITS4 (White *et al.*, 1990) regions was amplified and then

sequenced. DNA extractions were performed according to an earlier described procedure (Brillowska-Dabrowska *et al.*, 2013). 2x Master Mix HighGC (A&A Biotechnology) was applied for all of the PCR assays performed. PCR products were purified (Clean-up, A&A Biotechnology) and sequenced (Macrogen).

Table 2. *In vitro* echinocandin susceptibility test results of 6 rare isolates of *Candida* spp.

Species	Number of isolates	Place of isolation	MIC value [mg/l] of:		
			AND	MCF	CSP
<i>C. inconspicua</i>	1444 W	–	4	4	4
<i>C. palmioleophila</i>	4 W	–	4	4	4
<i>C. palmioleophila</i>	368 S	sputum	1	0.5	1
<i>C. palmioleophila</i>	370 G	blood	0.008	0.008	0.016
<i>C. palmioleophila</i>	377 G	liver cysts	0.008	0.008	0.016
<i>C. palmioleophila</i>	405 G	mouth	0.5	0.5	4

¹W, clinical sample isolated from a patient at Wrocław hospital; ²S, clinical sample isolated from a patient at Szczecin hospital; ³G, clinical sample isolated from a patient at Gdansk hospital

Sequence analysis was performed with VectorNTI (Informax).

Minimal Inhibitory Concentrations (MIC) were determined by broth microdilution and the results were read visually following 24 h incubation, as the lowest concentration of the drug that caused a complete growth inhibition. Also, *Candida albicans* ATCC 90028 and *Candida krusei* ATCC 6258 strains were used as controls. All tests were performed in triplicates and in case of discrepancies they were repeated. AND (Pfizer), CSP (Sigma-Aldrich), MCF (Astellas) were obtained as a standard powder.

RESULTS

Among 240 *Candida* samples, by sequencing an rRNA fragment we identified: 137 *C. albicans*, 72 *C. glabrata* 17 *C. krusei*, 8 *C. parapsilosis* and 6 strains belonging to two rare *Candida* species: 5 *C. palmioleophila* and 1 *C. inconspicua* strain. CHROMagar *Candida* correctly identified 93.4% *C. albicans*, 97.2% *C. glabrata*, 80% *C. krusei* strains. *C. palmioleophila* developed a turquoise color on CHROMagar, while *C. inconspicua* colonies were pink to violet.

Results of three echinocandins susceptibility examination tests are presented in Table 1. Among 137 *C. albicans* isolates, as many as 3 had shown a significant decrease in susceptibility to AND, 6 to CSP and 3 to MCF (minimal inhibitory concentration value for all echinocandins ≥ 1 mg/L); 2 isolates were intermediately resistant to AND, 3 to CSP, and 3 to MCF. In general, only 3/137 (2.2%) isolates of *C. albicans* were resistant to all echinocandins.

Out of 72 *C. glabrata* isolates, as many as 9 had shown a significant decrease in susceptibility to AND, 19 to CSP and 8 to MCF (MIC values: ≥ 0.5 mg/l, ≥ 0.5 mg/l, ≥ 0.25 mg/l, respectively). Only 1 isolate was intermediately resistant to MCF and 22 to CSP, (MIC value ≥ 0.125 mg/l; ≥ 0.25 mg/l). Only 7 isolates were resistant to all three echinocandins.

In the case of *C. krusei* we observed a decrease in CSP susceptibility of 14/17 isolates. However, these isolates were sensitive to AND and MCF. According to the echinocandin mechanism of action and well known technical problems with establishing MIC for CSP, it is unlikely that such a large percentage of isolates would show resistance only to one antibiotic from this group. Thus, these *C. krusei* isolates were probably not resistant to echinocandins because they were neither resistant to AND nor MCF. We identified only 1 isolate which was

resistant to three echinocandins (MICs value ≥ 4 mg/L for all echinocandins).

Among 8 *C. parapsilosis* we identified one resistant isolate to all echinocandins (MIC values ≥ 8 mg/l).

The MIC values of rare species of *Candida* were very high, but there is no echinocandin breakpoint established for these species (probably due to the low frequency of occurrence). The MIC value ≥ 4 was observed for one isolates of *C. palmioleophila*, and the same MIC value for the three echinocandin is exhibited by *C. inconspicua*. Two isolates of *C. palmioleophila* had MIC values ≤ 0.016 mg/l. The two isolates had a different MIC value depending on the examined antimycotics. The results of echinocandin susceptibility testing of these rare *Candida* isolates are listed in Table 2.

DISCUSSION

Epidemiological studies on *Candida* infections are conducted in many countries (Choi *et al.*, 2009). Various data are available on the prevalence of resistance to echinocandins among fungi of the *Candida* genus. These studies report that the occurrence of resistant isolates varies depending on the site of infection and the patient population. Previous epidemiological studies on resistance of *Candida* spp. in Poland are an insufficient source of data. There are two reports (Szymankiewicz & Dancewicz, 2008; Wieczorek *et al.*, 2008) from 2008 on caspofungin susceptibility testing performed with E-tests on isolates collected in the Polish hospitals. All of the 29 and 93 examined *Candida* isolates were susceptible to echinocandins. Another two reports from 2012 and 2014 had shown that there were no resistant *Candida* isolates within the 10 and 150 specimens collected in the Polish hospitals (Kurnatowska *et al.*, 2012; Golaś *et al.*, 2014). The latest echinocandin susceptibility testing was performed with E-tests in 2017. Only 46 isolates were examined and echinocandin resistance was not found (Sulik-Tyszka *et al.*, 2017).

Our research has shown that the echinocandin resistance of *Candida* isolates is a problem in Poland, especially within non-albicans species – 9.7% *C. glabrata* isolates were echinocandins resistant (7/72). Echinocandins susceptibility testing had shown that out of all the 240 isolates of *Candida* spp., 14 (5.8%) were resistant to AND; 40 (16.6%) to CSP, and 13 (5.4%) to MCF.

What is very interesting, we isolated 6 isolates belonging to two species that are rarely identified as a cause of human infections. *C. inconspicua* is described in the



literature as a fluconazole resistant and amphotericin B susceptible and is isolated from immunocompromised patients (Baily *et al.*, 1997; Sugita *et al.*, 2004; Guitard *et al.*, 2013; Majoros *et al.*, 2005). We identified one isolate of *C. inconspicua* which was characterized by very high echinocandins MIC.

Out of 5 *C. palmioloephila* isolates, 3 were characterized by high echinocandins MIC value. According to a variety of data, *C. palmioloephila* could be resistant to fluconazole and susceptible to other antimycotics, e.g. echinocandins (Liu *et al.*, 2017; Meletiadiis *et al.*, 2016), but there is also some information about elevated caspofungin MIC of *C. palmioloephila* (Brilhante *et al.*, 2017). *C. palmioloephila* were found in animal microflora (Sokół *et al.*, 2018) and there are only a few data available on *C. palmioloephila* as an etiological agent of human infections (Trouvé *et al.*, 2017).

It should be emphasized that data on previous echinocandins exposure (type and duration of antifungal therapy of patients) of the isolates examined in our study are not available. However, this does not change the fact that we indicate the problem of echinocandin resistance in Poland. Moreover, as the number of infections caused by *Candida* species resistant to fluconazole which is applied as the first line drug in candidiasis treatment in Poland increases, the occurrence of echinocandins resistance within *Candida* isolates should be examined.

Declaration of interest

The authors report no conflicts of interest.

Ethics approval

This study was exempt for ethics board approval as patient-specific public health information was not collected.

REFERENCES

Baily GG, Moore CB, Essayag SM, de Wit S, Burnie JP, Denning DW (1997) *Candida inconspicua*, a fluconazole-resistant pathogen in patients infected with human immunodeficiency virus. *Clin Infect Dis* **25**: 161–163

Brilhante RSN, Silva ALD, Monteiro FOB, et al (2017) Yeasts from Scarlet ibises (*Eudocimus ruber*): A focus on monitoring the antifungal susceptibility of *Candida famata* and closely related species. *Med Mycol* **55**: 725–732. <https://doi.org/10.1093/mmy/myw144>

Brillowska-Dąbrowska A, Michalek E, Saunte DM, Nielsen SS, Arendrup MC (2013) PCR test for *Microsporium canis* identification. *Med Mycol* **53**: 576–579. <https://doi.org/10.3109/13693780903531579>

Castanheira M, Woosley LN, Diekema DJ, et al (2010) Low prevalence of *fls1* hot spot 1 mutations in a worldwide collection of *Candida* strains. *Antimicrob Agents Chemother* **54**: 2655–2659. <https://doi.org/10.1128/AAC.01711-09>

Choi HK, Jeong SJ, Lee HS, Chin BS, Choi SH, Han SH, Kim MS, Kim CO, Choi JY, Song YG, Kim JM (2009) Blood stream infections by *Candida glabrata* and *Candida krusei*: a single-center experience. *Korean J Intern Med* **24**: 263–269. <https://doi.org/10.3904/kjim.2009.24.3.263>

Clinical and Laboratory Standards Institute. Reference Method for Broth Dilution Antifungal Susceptibility Testing of Yeasts. Fourth Informational Supplement. CLSI document M27-S4 2012. Wayne PA: Clinical and Laboratory Standards Institute 2012.

Cornely OA, Vazquez J, Waele J, Betts R, Rotstein C, Nucci M, Pappas PG, Ullmann AJ (2014) Efficacy of micafungin in invasive candidiasis caused by common *Candida* species with special emphasis on non-albicans *Candida* species. *Mycoses* **57**: 79–89. <https://doi.org/10.1111/myc.12104>

Dzierżanowska-Fangrat K, Romanowska E, Gryniewicz-Kwiatkowska J, Migdal M, Witulska K, Ryżko J, Kaliciński P, Książczyk J, Nadkowska P (2014) Candidaemia in a Polish tertiary paediatric hospital, 2000 to 2010. *Mycoses* **57**: 105–109. <https://doi.org/10.1111/myc.12107>

Golaś M, Netsvetyayeva I, Sikora M, Piskorska K, Sulik-Tyszka B, Swoboda-Kopec E (2014) Trends in antifungal susceptibility of *Candida* species – one year observation. *Pol J Microbiol* **63**: 217–222

Grossman NT, Chiller TM, Lockhart SR (2014) Epidemiology of echinocandin resistance in *Candida*. *Curr Fungal Infect Rep* **8**: 243–248. <https://doi.org/10.1007/s12281-014-0209-7>

Guitard J, Angoulvant A, Letscher-Bru V, L'Ollivier C, Cornet M, Dalle F, Grenouillet F, Lacroix C, Vekhoff A, Maury E, Caillot D, Charles PE, Pili-Floury S, Herbrecht R, Raffoux E, Brethon B, Hennequin C (2013) Invasive infections due to *Candida norvegensis* and *Candida inconspicua*: report of 12 cases and review of the literature. *Med Mycol* **51**: 795–799. <https://doi.org/10.3109/13693786.2013.807444>

Kurnatowska A, Kurnatowski P, Horwatt-Bożyczko E, Kurnatowska AJ (2012) Minimal inhibitory concentration (MIC) of caspofungin and itraconazole inhibiting growth of *Candida* strains calculated from the linear regression equation. *Adv Med Sci* **57**: 148–151. <https://doi.org/10.2478/v10039-012-0022-x>

Liu WL, Lai CC, Li MC, Wu CJ, Ko WC, Hung YL, Tang HJ, Hsueh PR (2017) Clinical manifestations of candidemia caused by uncommon *Candida* species and antifungal susceptibility of the isolates in a regional hospital in Taiwan, 2007–2014. *J Microbiol Immunol*. <https://doi.org/10.1016/j.jmii.2017.08.007>

Majoros L, Kardos G, Szabó B, Sipiczki M (2005) Caspofungin susceptibility testing of *Candida inconspicua*: correlation of different methods with the minimal fungicidal concentration. *Antimicrob Agents Chemother* **49**: 3486–3488. <https://doi.org/10.1128/AAC.49.8.3486-3488.2005>

Meletiadiis J, Geertsen E, Curfs-Breuker I, Meis JF, Mouton JW (2016) *In vitro* activity of micafungin against common and rare *Candida* species with the EUCAST, CLSI and E-test method: Intra- and inter-laboratory agreement. *Antimicrob Agents Chemother* **60**: 6173–6178. <https://doi.org/10.1128/AAC.01027-16>

Montagna MT, Lovero G, Coretti C, Martinelli D, De Giglio O, Iatta R, Balbino S, Rosato A, Caggiano G (2015) Susceptibility to echinocandins of *Candida* spp. strains isolated in Italy assessed by European Committee for Antimicrobial Susceptibility Testing and Clinical Laboratory Standards Institute broth microdilution methods. *BMC Microbiol* **15**: 106. <https://doi.org/10.1186/s12866-015-0442-4>

Navrot U, Pajczkowska M, Fleischer M, Przondo-Mordarska H, Samet A, Piasecka-Pazik D, Komarnicka J, Sulik-Tyszka B, Swoboda-Kopec E, Ciešlik J, Mikucka A, Gospodarek E, Ozorowski T, Mól A, Tryniszewska E, Klosowska W, Krawczyk M, Golec K, Szymaniak L, Giedrys-Kalemba S, Bilka I, Prawda-Zolotar J, Juszczyk-Grudzińska M, Wróblewska M, Burdynowski K (2013) Candidaemia in Polish hospitals—a multicentre survey. *Mycoses* **56**: 576–581. <https://doi.org/10.1111/myc.12077>

Pappas PG, Kauffman CA, Andes DR, Clancy CJ, Marr KA, Ostrosky-Zeichner L, Reboli AC, Schuster MG, Vazquez JA, Walsh TJ, Zaoutis TE, Sobel JD (2015) Clinical practice guideline for the management of candidiasis: 2016 update by the Infectious Diseases Society of America. *Clin Infect Dis* **62**: e1–e50. <https://doi.org/10.1093/cid/civ933>

Perlin D (2015) Echinocandin Resistance in *Candida*. *Clin Infect Dis* **61**: 612–617. <https://doi.org/10.1093/cid/civ791>

Sanguinetti M, Posteraro B, Lass-Flörl C (2015) Antifungal drug resistance among *Candida* species: mechanisms and clinical impact. *Mycoses* **5**: 2–13. <https://doi.org/10.1111/myc.12330>

Sokół I, Gawel A, Bobrek K (2018) The prevalence of yeast and characteristics of the isolates from the digestive tract of clinically healthy turkeys. *Avian Dis* **62**: 286–290. <https://doi.org/10.1637/11780-121117-Reg.1>

Sugita T, Takeo K, Ohkusu M, et al (2004) Fluconazole-resistant pathogens *Candida inconspicua* and *C. norvegensis*: DNA sequence diversity of the rRNA intergenic spacer region, antifungal drug susceptibility, and extracellular enzyme production. *Microbiol Immunol* **48**: 761–766. <https://doi.org/10.1111/j.1348-0421.2004.tb03602.x>

Sulik-Tyszka B, Ciešlik J, Niewiński G, Wróblewska M (2017) Epidemiological analysis and evaluation of *in vitro* susceptibility to micafungin of clinical strains of *Candida* spp. causing fungaemia in patients hospitalised in intensive care unit. *Forum zakażeń* **8**: 157–161. (in Polish)

Szymankiewicz M, Dancewicz M (2008) *In vitro* activity of voriconazole and caspofungin against *Candida* spp. strains evaluated by E-test. *Mikol Lek* **15**: 13–15 (in Polish)

Trouvé C, Blot S, Hayette MP, Jonckheere S, Patteet S, Rodriguez-Villalobos H, Symoens F, Van Wijngaerden E, Lagrou K (2017) Epidemiology and reporting of candidaemia in Belgium: a multicentre study. *Eur J Clin Microbiol Infect Dis* **36**: 649–655. <https://doi.org/10.1007/s10096-016-2841-3>

White TJ, Bruns T, Lee S, Taylor JW (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In PCR Protocols: A Guide to Methods and Applications. Academic Press, Inc., New York **18**: 315–322. <https://doi.org/10.3109/13693786.2012.755741>

Więczorek P, Sacha P, Żórawski M, Jakoniuk P, Tryniszewska E (2008) *In vitro* activity of caspofungin against strains of the genus *Candida*. *Mikol Lek* **15**: 135–139 (in Polish)