Drug susceptibility of *Candida* isolated from the surfaces of mobile phones and hands

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ABSTRACT

Introduction: The mycological literature currently devotes much attention to the issue of reduced fungal susceptibility to commonly used antifungal drugs.
Purpose: To assess drug susceptibility of *Candida* strains isolated from samples collected from the surfaces of mobile phones and the hands of their owners. A total of 175 mobile telephones belonging to students and lecturers of the Medical University of Bialystok and University Hospital personnel as well as 175 hands of these phone owners were included in the mycological evaluation.
Results: The rate of *Candida* contamination of personal mobile phones was more than 70.0%. *C. glabrata* strains were primarily isolated from the collected material (89.1% - hands; 74.9% - mobile phones). *C. albicans* strains showed susceptibility to most antimycotics, with the highest susceptibility to 5-fluorocytosine, and the lowest to fluconazole. *C. glabrata* showed the lowest susceptibility to fluconazole and miconazole, and the highest to ketoconazole. *C. krusei* were relatively very sensitive to antibiotics, except for fluconazole. None of the isolated strains showed resistance to more than three types of drugs.
Conclusion: This study demonstrated that mobile phones are potentially vehicles for pathogenic *Candida* strains in a university and hospital settings.
Keywords *Candida,* isolated, mobile phones

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INTRODUCTION

Mobile phones are widely used by healthcare workers and could be colonized by potential bacteria and fungi pathogens. Mobile phones are potential vectors for transferring nosocomial pathogens between health care workers', patients, and the community [1-2]. The mobile phones are used routinely all day long but they are cleaned rarely by medical staff.

Numerous previous studies assessed contamination of mobile phones among the health care workers [2-5].

Ulger et al. [2] determined the contamination rate of the healthcare workers' mobile phones and hands in operating room and intensive care units. 200 healthcare workers were screened; samples from the hands of 200 participants and 200 mobile phones were cultured. They found that 94.5% of phones demonstrated evidence of bacterial contamination with different types of bacteria. In a similar study, Foong et al. [3] investigated the potential role of mobile phones as a reservoir for bacterial colonization and the risk factors for bacterial colonisation in a hospital setting. They screened 226 staff members at a regional Australian hospital (146 doctors and 80 medical students). They found a high level of bacterial contamination 74% on the mobile phones of staff members in a tertiary hospital.

Very few studies [6,7] have been carried out to understand the role played by mobile phones in spreading fungi especially nosocomial pathogens.

Candida spp. are currently the fourth most common cause of bloodstream infections in US hospitals, and the third most common cause of bloodstream infections in the intensive care unit [8].

The mycological literature devotes much attention to the issue of fungal resistance and reduced susceptibility to commonly used antifungal drugs [8-13], and it emphasizes that the process is still in progress, especially for azole chemotherapeutics (ketoconazole, tioconazole, miconazole, fluconazole, itraconazole).

For example, *C. glabrata* and *C. krusei* show primary resistance to fluconazole [11]. Resistance to amphotericin B most frequently occurs in *C. parapsilosis*, *C. lusitaniae*, *C. quillermondii*, *C. tropicalis*, and *C. krusei*. The growing resistance of *Candida* strains to azole antifungals also should be mentioned [14-15].

To our knowledge, there are no reports on drug susceptibility of fungal strains isolated from mobile phone surfaces in the scientific literature. Since mobile phones are regarded as potential vectors of infection, it seemed advisable to investigate the selected aspects of pathogenicity of fungi isolated from mobile phone surfaces, especially in light of the fact that the world literature lacks such reports.

The aim of the study was to asses the drug susceptibility of *Candida* strains isolated from samples collected from the surfaces of mobile phones and the hands of their owners.

MATERIALS AND METHODS

The Bioethics Committee of the Medical University of Bialystok approved the study, approval no. RI-002/489/2010.

A total 175 staff - 75 students and 25 lecturers of the Medical University of Bialystok and 100 healthcare staff of the University Hospital were screened; cultures were subsequently obtained from the dominant hand of participants and their mobile phones at the same time. The sampling of the dominant hand (including ventral surface) and mobile phone (surface of the contact with the ventral hand) of the participants were performed by Count-TacTM.

We used Count-TactTM applicator using Count-Tact plates (bioMerieux) containing a medium complying with the requirements of the Draft European Standard CEN/TC 243/WG2. CandiSelect (Bio-Rad) was used to identify yeast-like fungi.

Drug susceptibility was assessed using FUNGITEST® (Sanofi Diagnostics Pasteur) for the analysis of fungal growth in the presence of six drugs, such as 5-fluorocytosine, amphotericin B, miconazole, ketoconazole, itraconazole and fluconazole used at two concentrations, in modified RPMI 1640 medium, in the presence of a redox indicator. The mycological procedures were in accordance with the manufacturer's instructions.

The results were interpreted according to the manufacturer's instructions, always by the same person and always with reference to the color of two wells containing the same drug: a blue color in both wells indicated an *in vitro* susceptible strain; a pink color at lower concentrations and a blue color at higher concentrations indicated an *in vitro* strain with low susceptibility; and a pink color in both wells indicated an *in vitro* resistant strain.

Numerical characteristics of the evaluated parameters and percentage values, the Chi^2 test was used for statistical analysis. P values < 0.05 were considered significant. Statistica 10.0 PL software was used for these analyses.

RESULTS

In this study, the rate of *Candida* contamination of personal mobile phones was more than 70.0%. We isolated the following strains from the material collected from the surfaces of the hands of mobile phone owners: *C. glabrata* (89.1%); *C. albicans* (83.4%); *C. krusei* (69.7%); and *C. tropicalis* (5.1%). We isolated the following strains from the material collected from mobile

phone surfaces: *C. glabrata* (74.9%); *C. albicans* (65.1%); *C. krusei* (54.3%), and *C. tropicalis* (6.3%). Significant correlations in *Candida* contamination between hands and mobile phones were found as follow: *C. albicans* R=0.450, p<0.001; *C. glabrata* R=0.260 P=0.0039; *C. krusei* R=0.290, p=0.0089; *C. tropicalis* R=0.152, p=0.0431.

C. albicans strains showed susceptibility to most types of antimycotics, with the highest susceptibility to 5-fluorocytosine, and the lowest to fluconazole (Table 1). In the case of isolates from the hand, none of the strains showed resistance to amphotericin B; in the case of isolates from mobile phones, none of the strains showed resistance to amphotericin B or miconazole. We observed more cases of resistant strains among the isolates from hand surfaces compared with mobile phones.

Table 1. Assessment of drug susceptibility of *Candida albicans* strains

Drug	**Susceptibility to antibiotic**					
	high susceptibility		**low susceptibility**		**resistant strain**	
Hand*						
5-fluorocytosine	97	66.4%	45	30.8%	4	2.7%
amphotericin B	76	52.1%	70	47.9%	0	0.0%
miconazole	68	46.6%	64	43.8%	14	9.6%
ketoconazole	83	56.8%	39	26.7%	24	16.4%
itraconazole	87	59.6%	35	24.0%	24	16.4%
fluconazole	75	51.4%	27	18.5%	44	30.1%
Phone						
5-fluorocytosine	91	79.8%	22	19.3%	1	0.9%
amphotericin B	89	78.1%	25	21.9%	0	0.0%
miconazole	84	73.7%	30	26.3%	0	0.0%
ketoconazole	73	64.0%	39	34.2%	2	1.8%
itraconazole	83	72.8%	28	24.6%	3	2.6%
fluconazole	58	50.9%	37	32.5%	19	16.7%
hand vs phone Chi^2 test						
ad 5-fluorocytosine - p=0.009 ad amphotericin B p=0.0003 ad miconazole – p= 0.0000						
ad ketoconazole – p=0.0229 ad itraconazole – p=0.0003 ad fluconazole – p=0.0052						

C. glabrata showed the lowest susceptibility to fluconazole and miconazole, and the highest to ketoconazole (Table 2). Strains isolated from mobile phone surfaces showed slightly higher susceptibility compared with those from the hands of the respondents. Assessment of the significance of differences in the susceptibility level of *C. glabrata* isolated from hand and mobile phone surfaces showed no statistically significant differences in susceptibility to the analyzed drugs.

C. krusei showed a relatively high susceptibility to antibiotics, except for fluconazole (Table 3). The results we obtained for strains collected from hands and mobile phones were very similar. The highest resistance was observed for fluconazole. Assessment of the significance of differences in the susceptibility level of *C. krusei* isolated from hand and mobile phone surfaces. There were no statistically significant differences in susceptibility to the analyzed drugs.

Susceptibility assessment of *C. tropicalis* strains may indicate high randomness due to the small number of subjects colonized by these fungi. The results we obtained for strains collected from hands and mobile phones were similar (Table 4).

We also assessed the simultaneous resistance of the evaluated fungal strains to one or more of the tested antifungal drugs (Table 5). The drugs to which certain strains were resistant were summed for each individual who had fungal strains isolated from mobile phone or hand surfaces. None of the isolated strains showed resistance to more than three types of drugs. Since we were able to perform the analysis only based on the results for individuals who had fungal strains of a certain type isolated from both their hand and mobile phone surfaces, we excluded the two least common strains from analysis.

The rate of routine cleaning of medical personnel's mobile phones was 67.4%, which means 32.6% of the participants never cleaned their mobile phones.

Table 2. Assessment of drug susceptibility of *Candida glabrata s*trains

Drug	Susceptibility to antibiotic					
	high susceptibility		low susceptibility		resistant strain	
Hand						
5-fluorocytosine	100	64.1%	54	34.6%	2	1.3%
amphotericin B	102	65.4%	51	32.7%	3	1.9%
miconazole	76	48.7%	77	49.4%	3	1.9%
ketoconazole	118	75.6%	38	24.4%	0	0.0%
itraconazole	101	64.7%	52	33.3%	3	1.9%
fluconazole	72	46.2%	72	46.2%	12	7.7%
Phone						
5-fluorocytosine	80	60.6%	49	37.1%	3	2.3%
amphotericin B	82	62.1%	48	36.4%	2	1.5%
miconazole	74	56.1%	56	42.4%	2	1.5%
ketoconazole	99	75.0%	33	25.0%	0	0.0%
itraconazole	91	68.9%	39	29.5%	2	1.5%
fluconazole	53	40.2%	69	52.3%	10	7.6%
hand vs phone Chi^2 test ad 5-fluorocytosine – p=0.2496 ad amphotericin B – p=0.8979 ad miconazole – p=0.2389 ad ketoconazole – p=0.7317 ad itraconazole – p=0.8203 ad fluconazole – p=0.1307						

Table 3. Assessment of drug susceptibility of *Candida krusei* strains

Drug	Susceptibility to antibiotic					
	high susceptibility		low susceptibility		resistant strain	
Hand						
5-fluorocytosine	81	66.4%	36	29.5%	5	4.1%
amphotericin B	93	76.2%	28	23.0%	1	0.8%
miconazole	80	65.6%	42	34.4%	0	0.0%
ketoconazole	76	62.3%	46	37.7%	0	0.0%
itraconazole	98	80.3%	24	19.7%	0	0.0%
fluconazole	0	0.0%	9	7.4%	113	92.6%
Phone						
5-fluorocytosine	57	70.4%	21	25.9%	3	3.7%
amphotericin B	66	81.5%	15	18.5%	0	0.0%
miconazole	53	65.4%	28	34.6%	0	0.0%
ketoconazole	56	69.1%	25	30.9%	0	0.0%
itraconazole	69	85.2%	12	14.8%	0	0.0%
fluconazole	0	0.0%	6	7.4%	75	926%
hand vs phone Chi^2 test ad 5-fluorocytosine - 0.361 ad amphotericin B - 0.361 ad miconazole - 0.875 ad ketoconazole - 0.186 ad itraconazole - 0.637 ad fluconazole - 1.000						

Table 4. Assessment of drug susceptibility of *Candida tropicalis* strains

Drug	Susceptibility to antibiotic					
	high susceptibility		low susceptibility		resistant strain	
Hand						
5-fluorocytosine	7	77.8%	2	22.2%	0	0.0%
amphotericin B	4	44.4%	5	55.6%	0	0.0%
miconazole	5	55.6%	4	44.4%	0	0.0%
ketoconazole	8	88.9%	1	11.1%	0	0.0%
itraconazole	9	100.0%	0	0.0%	0	0.0%
fluconazole	0	0.0%	6	66.7%	3	33.3%
Phone						
5-fluorocytosine	4	44.4%	5	55.6%	0	0.0%
amphotericin B	3	33.3%	6	66.7%	0	0.0%
miconazole	9	100.0%	0	0.0%	0	0.0%
ketoconazole	8	88.9%	1	11.1%	0	0.0%
itraconazole	8	88.9%	1	11.1%	0	0.0%

Table 5. Simultaneous resistance of the evaluated fungal strains to one or more of the tested antifungal drugs

Number of drugs a given fungal strain was resistant to	Fungal strain															
	Candida albicans				*Candida glabrata*				*Candida krusei*				*Candida tropicalis*			
	hand		phone		hand		phone		hand		phone		hand		phone	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
0	52	36	91	80	137	88	114	86	9	7	6	7	6	67	5	56
1	79	54	21	18	16	10	17	13	107	88	72	89	3	33	4	44
2	14	10	2	2	2	1	1	1	6	5	3	4	0	0	0	0
3	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0

DISCUSSION

In this study, the rate of *Candida* contamination of personal mobile phones among medical students and physicians was more than 70.0%. We demonstrated *C. glabrata*, *C. albicans*, and *C. krusei* were the most common strains isolated from the material collected from mobile phone surfaces. *Candida* strains showed susceptibility to most types of antimycotics. We also demonstrated significant correlations in *Candida* strains contamination between hands and mobile phones were found.

The possibility transmissions of nosocomial pathogens by electronic devices such as personal digital assistants, handheld computers, and mobile phones were previously reported and some of them were epidemiologically important drug-resistant pathogens [16-18].

Healthcare workers can also carry *Candida* on their hands [19-20]. Seventy-five percent of the nurses and 81% of the nonnurses were found to harbor yeasts on their hands; 58% of nurses and 38% of nonnurses were carrying *Candida* spp. [19] Yildirim et al. isolated *Candida* spp., from hands of 30.7% nurses, 25.8% resident doctors, and 28.6% laboratory workers.

There have been a few outbreaks of candidemia linked to healthcare workers' hands, so is important for preventing the spread of infections [21-22].

C. albicans is the most prevalent opportunistic fungal pathogens of human. *Candida* can live as a harmless commensal of humans, and is carried in almost half of the population [23] Colonization of *Candida i*n distinct sites including skin, oral gastrointestinal tract and vaginal mucosal surfaces are extremely common in healthy individuals. The *Candida* infection is more prevalent in patients with impaired host defenses, during chemotherapies, organ transplants, cancer therapy, use of prosthetic devices, patients using broad-spectrum antibiotics and in AIDS patients

Over the last decade, there have been important changes in the epidemiology of *Candida* infections and antifungal agents used to treat these infections. In recent years, *Candida* spp. have emerged as important causes of invasive infections among patients in intensive care units, in immunocompromised patients and use indwelling medical devices [24].

Non-*C.albicans s*pecies such as *C. glabrata, C. tropicalis* and *C. parapsilosis* are now frequently identified as human pathogens. Furthermore, infections (candidiasis) due to *C. tropicalis* have increased dramatically on a global scale thus proclaiming this organism to be an emerging pathogenic yeast [25].

In the hospitals, usually attention is paid to changing clothes, removing jewellery, covering hair, and hand hygiene to reduce the transfer of microorganisms from the external clinical environment into the hospitals rooms. However, less attention is paid to using mobile phones in the hospitals. So it is important to know the *Candida* load on mobile phones used by students and medical staff within the university and hospitals. Mobile phones should be regarded as the potential source of nosocomial infections with *Candida*.

In general, *Candida* species are not assumed to be primary causative pathogens in ventilator-associated pneumonia patients [26].

In a post-mortem study in patients with evidence of pneumonia at autopsy, none of the subjects with a tracheal aspirate or bronchoalveolar lavage culture positive for *Candida* species had histopathological evidence of invasive *Candida* growth [27].

However, there is evidence that colonisation of the lower respiratory tract by *Candida* species promotes the development of pneumonia by creating biofilms that are capable of holding other micro-organisms [28].

It is suggested that multifocal *Candida* spp. findings increase the risk of a systemic *Candida* spp. infection, and thereby increase risk for morbidity and mortality. Azoulay et al. [29] found in a multicenter cohort of 800 patients that pulmonary *Candida spp.* colonization was significantly associated with an increased risk of nosocomial pneumonia and prolonged length of stay at the intensive care unit.

Fungal pneumonia is an infectious process in the lungs caused by one or more endemic or opportunistic fungi. Fungal infection occurs following the inhalation of spores, after the inhalation of conidia, or by the reactivation of a latent infection. Hematogenous dissemination frequently occurs, especially in an immunocompromised host. Opportunistic fungal organisms (e.g. *Candida* species, *Aspergillus* species, *Mucor* species) tend to cause pneumonia in patients with congenital or acquired defects in the host immune defenses [30].

In the present study, *C. albicans* strains isolated from hand surfaces did not show resistance to amphotericin B, and the strains from mobile phone surfaces were not resistant to amphotericin B nor miconazole.

The literature [31-32] emphasized that *C. krusei* and *C. glabrata* strains have a natural resistance to fluconazole and decreased susceptibility to 5-fluorocytosine. In our study, *C. glabrata* showed the highest resistance to fluconazole from hands and mobile phones.

There has been an increase in the occurrence of drug-resistant strains of bacteria since the introduction of antibiotics. An increase in drug resistance has also been observed among *Candida* spp.

In our study, *C. krusei* isolated from mobile phone and hands showed each 92.6% resistance to fluconazole; 70.4% of isolates from mobile phones and 66.4% from hand surfaces were susceptible to 5-fluorocytosine. Isolates from hand and mobile phone surfaces occasionally showed resistance to more than three types of drugs. This is in agreement with previous reports [33-35].

Krajewska-Kułak et al. [36] assessed the susceptibility of the yeast-like fungi strains using the Fungitest method The yeast-like fungi strains isolated from 406 patients with symptoms of candidiasis (oral cavity, vagina, urethra, skin, nails, and stomach) were evaluated. Differences between the susceptibility of strains isolated from different sites of the body to tested drugs were found. High resistance of tested strains to several antimycotics were identified. Fungitest is an easy and effective method in assessing the susceptibility of yeast-like fungi strains to antimycotics.

In the present study, we also used Fungitest method to assess drug susceptibility. We found that *C. albicans* strains were more resistant to antifungal agents isolated from hands compared to isolates from mobile phones. In contrast, the susceptibility of *C. glabrata* strains from mobile phone surfaces was higher compared with strains collected from the hands. Although the results obtained for *C. krusei* and *C. tropicalis* isolates from hand and mobile phone surfaces were very similar.

In our study, susceptibility to fluconazole was shown by 64.1% of *C. glabrata* strains isolated from hand surfaces and 60.6% of strains isolated from mobile phones. In the case of *C. krusei*, none of the strains from hand or mobile phone surfaces was susceptible to fluconazole. Perhaps, strains isolated from mobile phone surfaces, as opposed to organic materials, may have different drug susceptibility.

In the present study, we identified fungi using selective, differential medium, CHROMagar Candida Medium, for isolation and identification of *C. albicans*, *C. tropicalis*, and *C. krusei*, which according to many authors [37-38] can easily be used for direct identification of *C. albicans*, *C. krusei* and *C. tropicalis*. Reports indicating high sensitivity and specificity of the differentiation of *Candida strains* grown on CHROMagar® Candida can be found in the literature [37-38].

Some authors reported a low rate of cleaning mobile phones by the medical staff. The rate of routine cleaning of healthcare worker's mobile phones was 10.5%, which means 89.5% of the participants never cleaned their mobile phones [1]. In another study, [39] only 37% of healthcare workers cleaned their phones. And, 75% of the participants did not view a ban on phones as a practical solution was they found to be an infection risk.

In our study, the rate of routine cleaning of medical personnel's mobile phones was rather high, (67.4%), which means 32.6% of the participants never cleaned their mobile phones.

The education of medical personnel mobile phone as source of *Candida* contamination, hand hygiene, environmental disinfection, and disinfection methods of mobile phones are of great importance. Developing active preventive strategies like routine decontamination of mobile phones with alcohol containing disinfectant materials might reduce cross-infection.

CONCLUSIONS

1. *Candida glabrata*, *Candida albicans*, and *Candida krusei* were the most common strains isolated from the material collected from mobile phone surfaces.
2. In the case of *C. albicans* and *C. glabrata*, isolates from hand surfaces were more resistant; whereas in the case of *C. krusei* and *C. tropicalis*, resistance was comparable for both strains isolated from hand and phone surfaces.
3. Isolates from hand and mobile phone surfaces sporadically showed resistance to more than three types of drugs, and these most often included *C. glabrata* isolated from hand surfaces.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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