Effects of biofilm formation and plethora of Candida species causing ailments: a mini review

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Abstract

Biofilm formation is an independent predictor of higher mortality rate and significant virulence factor that increase the dissemination ability and persistence of Candida species. However, Candida species distribution differs in population based studies evaluated in different geographical locations. This study aimed to evaluate the biofilm associated mortality rate, spectrum and resistance profile of Candida species. A systemic literature review was carried out to evaluate all current epidemiology that reports the incidence of the biofilm associated mortality rate, spectrum and resistance profile of Candida species. Several studies used optical density of the biomass from culture to measure biofilm formation. Data regarding the prevalence of Candida species, in vitro biofilm assay and rate of biofilm-related Candida species in clinical isolates were also extracted from the case-control, cohort, and retrospective studies. The result of this study shows that the mortality rate due to biofilm associated infections ranged from 6.9% to 70.0% and biofilm formation varied greatly from 27.2% to 100% evaluated from different published studies. Candida albicans was the predominant pathogen and the percentage frequency of the isolates ranged from 36.3% to 78.5%. The distribution of Candida species from 2016 to 2020 revealed that Candida albicans (39.42%) had the highest percentage frequency. High prevalence of Candida species was reported in 2018 (28.2%). The current data revealed that United Kingdom, Spain, Austria and Norway shows resistance profile for Candida tropicalis, Candida albicans, Candida parapsilosis and Candida glabrata. Biofilm formation is considered as potential risk factor of higher mortality rate and effective antifungal agents to eliminate or reduce this menace is urgently needed. The reports of the biofilm-forming potentials and properties among Candida species could provide a remarkable step toward the improvement of Candida infection therapies.

1.0 Introduction

Candida species have emerged as one of the most common causes of invasive fungal infections, and described as an opportunistic infection or systemic mycosis. National Institutes of Health reported that biofilms are significantly responsible either directly or indirectly, for more than 80% of all microbial infections in the United States (Atienza-Carrera et al., 2022). Candida species can produce well-structured biofilms, contained multiple types of cell and microbial species, resulting to an intrinsic resistance against various forms of stress factors such as immune defense mechanisms and multiple antifungal agents (Polke et al., 2015). The population group that are more prone for invasive candidiasis includes patients with a central venous catheter, hematopoietic cell and solid organ transplantation, parenteral nutrition, recent abdominal surgery, hematological and solid organ malignancy or critical ill patients (Tsay et al., 2020). Premature newborns and patients that received broad spectrum of antibiotics are also prone to invasive candidiasis. In the early 1990s, the number of episode...
of sepsis and fungal infections has been increasing and have become a major challenge in hospitals (Guinea, 2014). Several studies have reported the incidence of candidemia as 72.8 per million in population and Candida species remains the most predominant causative agents of invasive fungal infections compared to mucormycosis and aspergillosis (Rees et al., 1998). Candida related infection is a consequence of advances in health care especially in developing countries. Currently, the incidence of candidemia has been increasing, even with the progressive development in diagnostic criteria, commercialization of new antifungal agents and the implementation methods to prevent the dissemination of fungal infections (Pfeller and Diekema, 2007). Most of the infections caused by invasive Candida species, the diagnosis still remain complicated to laboratory scientists or clinicians using blood cultures for identification of the clinical isolates (Berenguer et al., 1993). The true incidence and epidemiology of invasive candidiasis is uncertain in most of the reported studies. The hospitalization bill for each episode of Candida related infections is approximately 40,000 USD with attributable mortality rate of 15 – 35% in adults and 10 – 15% for neonates in some studies (Guinea, 2014). Late mortality is associated with factors such as baseline condition of the host, and early mortality is associated with factors related to the early removal of central venous catheters and appropriate antifungal treatment in patients (Puig-Asensio et al., 2014). Currently, this systemic fungal infection is the 4th leading nosocomial infection and reported about 40% of mortality rate in the United Sates (Thompson et al., 2019). Systemic mycosis caused by Candida species can be categorized into three classes which include deep-seated candidiasis, bloodstream infection (candidemia) or combination of both classes (Lagunes and Rello, 2016). Some culture media are used specifically to diagnose deep candidiasis from tissue biopsies, and blood culture is used commonly to diagnose candidemia. However, the gold standard for the diagnosis of invasive fungal infection is the culture media (Pappas et al., 2015). Nosocomial infections are closely related with biofilms growing attached to host tissues or medical devices (Chandra and Mukherjee, 2015). Candida biofilm formation strains are associated with significant mortality rate, apparently correlated with the poor permeability of the matrix to the antifungal agents (Tascini et al., 2017). Biofilms are the common growth state of numerous microorganisms, being a zone of irreversible adherent cells with different structural and phenotypic properties when compared to planktonic cells (Atienza-Cerrera et al., 2022). It was reported that Candida biofilms suppress the innate immunity system of the host and the dynamics of biofilm-host association is not fully understood (Johnson et al., 2016). The biofilm formation forming fungal cells are commonly found on hospital surfaces which usually persist on biomedical devices and nosocomial environment (Tascini et al., 2017). Candida species resist many antifungal agents, indicated a serious menace for public health. In Europe, the incidence of Candida bloodstream increased from 2.2 cases in every 100,000 population to 3.2 cases in 100,000 population annually (Koehler et al., 2019). The trends in resistance profile against echinocandines and azole can distort the treatment of Candida bloodstream infection due to inadequate therapeutic options. Candida glabrata and Candida parapsilosis are also common clinical isolates causing invasive candidiasis and prevalence changes at different locations. In Northern Europe, Candida glabrata account for 9% to 21.1% of Candida bloodstream infection cases while in the Mediterranean region, Candida parapsilosis is more common (Galía et al., 2022). Currently, surveillance studies have raised the concern regarding the context of multidrug resistant data among non-albicans Candida species and Candida albicans (Arendrup et al., 2017). In the global context of Candida auris, the preservation of current antifungal therapy has increased due to nosocomial outbreak with high mortality and morbidity. The Centers for Disease Control and Prevention (CDC) added fungal infections in the priority list of the Antibiotic Resistance Threats Report in 2019 (Galía et al., 2022).

2.0 Materials and Methods
2.1 Data Selection and Search Strategy
This study was carried out following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) strategies (Zeng et al., 2015). Google Scholar, Web of Science, PubMed and Scopus databases were searched for relevant published articles using the following terms: candidemia, invasive candidiasis, candidiasis, bloodstream infections, effective antifungal drugs, biofilm formation, Candida species, biofilm associated infections, resistance data of Candida species, mortality rate associated with biofilm formation, prevalence and distribution of Candida species. In each electronic database, a combination of the mentioned terms was used to conduct the search again. The references of the relevant published articles was also searched for finding additional information. The data selection was based on human clinical isolates.

2.2 Eligibility Criteria
The major inclusion criteria included the published articles that reports the prevalence of biofilm associated to Candida species and the rate of biofilm formation including retrospective, cohort and case-control studies. The information regarding the geographical region of the study, the mortality rate,
and the use of antifungal therapy in clinical isolates were also extracted from the relevant studies. All studies without relevant data about prevalence of Candida species, biofilm formation, antifungal therapy against Candida isolates were excluded. Concerning antifungal resistance rate, only studies that used European Committee on Antimicrobial Susceptibility Testing EUCAST or standard susceptibility tests according to the Clinical and Laboratory Standards Institute (CLSI) was considered for this current study. Finally, articles without duplicate reports on different databases, full text available and studies with missing or unclear information was also excluded.

2.3 Statistical Analysis
Descriptive statistics (Frequency) of the distribution of Candida species were enumerated and subjected to graph profile using IBM® SPSS® Statistics version 25.0 (IBM® Corp., Armonk, NY, USA).

3.0 Results
Table 1 is the prevalence of biofilm formation and mortality rate. The result shows that the biofilm formation in this study varied greatly from 27.2% to 100% evaluated from different published studies. The mortality rate due to biofilm associated infections ranged from 6.9% to 70.0%. Figure 1 is the distribution of Candida species from the studies. The result shows that Candida albicans (34.1%) had the highest percentage frequency followed by Candida tropicalis (22.7%), Candida glabrata (15.9%), Candida parapsilosis (13.6%), Candida krusei (9.1%), Candida dublininesis (2.3%) and Candida guilliermondii (2.3%) respectively. Table 2 is the prevalence of Candida albicans and predominant Candida species. The result shows that the Candida albicans are the predominant pathogens and the percentage frequency of the isolates ranged from 36.3% (102 clinical isolates) to 78.5% (177 clinical isolates). Table 3 is the prevalence of Candida species from 2016 to 2020 in Istanbul, Turkey. The result from 2016 to 2020 shows that the common pathogen was Candida albicans (39.42%) followed by Candida parapsilosis (34.02%) and least pathogens were Candida guilliermondii (0.41%) and Candida dubliniensis (0.41%). High prevalence of Candida species was reported in 2018 (28.2%) compared to 2016 (14.1%), 2017 (18.3%), 2019 (24.5%) and 2020 (14.9%) respectively. Table 4 is the resistance data of Candida species from blood specimen. The result shows that the United Kingdom, Spain, Austria and Norway reported resistance profile for Candida tropicalis, Candida albicans, Candida parapsilosis and Candida glabrata. Currently, no study reported the resistance profile for other Candida species. Amphotericin B, anidulafungin, micafungin, voriconazole, fluconazole, posaconazole anditraconazole resistance in Candida species were the most frequent drug-species combination reported.

Table 1. Prevalence of biofilm formation and mortality rate

| Country  | Technique used to measure biofilm | Biofilm rate in number and percentage | Biofilm formation in number and percentage | Association between biofilm and resistance | Attributable mortality rate in number and percentage | References |
|----------|----------------------------------|--------------------------------------|------------------------------------------|------------------------------------------|---------------------------------------------------|------------|
| Hungary  | Using micro plate reader with crystal violet staining (550 nm) | 127/127 (100.0%) | 28 (22.0%) | 69 (54.4%) | 30 (23.6%) | No | 70 (55.1%) | (Vitalis et al., 2020) |
| Thailand | Using micro plate reader with yellow tetrazolium salt (490 nm) | 38/46 (82.6%) | 13 (28.3%) | 25 (54.3%) | No | 13 (34.2%) | (Pham et al., 2019) |
| Brazil   | Using micro plate reader with crystal violet staining (570 nm) | 13/13 (100.0%) | 3 (23.1%) | 7 (53.8%) | 3 (23.1%) | No | | (Herek et al., 2019) |
| Mexico   | Using micro plate reader with crystal violet staining (595 nm) | 89/89 (100%) | No | | 32 (35.9%) | | (Trevino-Rangel et al., 2018) |
| Italy    | Using micro plate reader with crystal violet staining (595 nm) | 190/190 (100.0%) | 68 (35.8%) | 38 (20.0%) | 84 (44.2%) | No | 89 (46.8%) | (Soldini et al., 2018) |
| Country   | Technique used to measure biofilm | Biofilm rate in number and percentage | Biofilm formation in number and percentage | Association between biofilm and resistance | Attributable mortality rate in number and percentage | References                  |
|-----------|-----------------------------------|--------------------------------------|-------------------------------------------|-------------------------------------------|------------------------------------------------|-----------------------------|
| India     | crystal violet staining (540 nm)  | 55/74 (74.3%)                        | No                                        |                                           |                                              | (Tulasidas et al., 2018)    |
| Italy     | Using micro plate reader with crystal violet staining (570 nm) | 57/89 (64.0%)                        | No                                        | 25 (43.9%)                                |                                              | (Tascini et al., 2017)     |
| Scotland  | Using micro plate reader with crystal violet staining (570 nm) | 245/280 (87.5%)                      | 56 (22.9%)                                | 144 (58.9%)                               | Yes                                          | (Rajendran et al., 2016)   |
| India     | Branchini’s method                | 31/80 (38.8%)                        | No                                        | 5 (16.1%)                                 |                                              | (Banerjee et al., 2015)    |
| Spain     | Using micro plate reader with crystal violet staining (550 nm) | 45/54 (83.3%)                        | No                                        |                                              |                                              | (Guembe et al., 2014)      |
| Brazil    | Christensen’s method              | 15/28 (53.6%)                        | No                                        | 6 (40.0%)                                 |                                              | (Rodrigues et al., 2014)   |
| Italy     | Using micro plate reader with yellow tetrazolium salt (490 nm) | 160/451 (35.5%)                      | 44 (27.5%)                                | 116 (72.5%)                               | No                                          | (Tortorano et al., 2013)   |
| Italy     | Using micro plate reader with yellow tetrazolium salt (490 nm) | 297/297 (100.0%)                     | 60 (20.2%)                                | 141 (47.5%)                               | No                                          | (Prigitano et al., 2012)   |
| Italy     | Phosphate Buffered Saline (405 nm) and Using micro plate reader with yellow tetrazolium salt (490 nm) | 84/207 (40.6%)                      | No                                        | 43 (51.2%)                                |                                              | (Tumbarello et al., 2012)   |
| Italy     | Phosphate Buffered Saline (405 nm) and Using micro plate reader with yellow tetrazolium salt (490 nm) | 80/294 (27.2%)                      | No                                        | 56 (70.0%)                                |                                              | (Tumbarello et al., 2007)  |
**Table 2. The prevalence of *Candida albicans* and predominant *Candida* species**

| S/N | Country       | Number of Clinical Isolates | Clinical Specimen          | Number and percentage of *Candida albicans* Isolates | Predominant *Candida* Species                                    | References                        |
|-----|---------------|-----------------------------|-----------------------------|------------------------------------------------------|------------------------------------------------------------------|-----------------------------------|
| 1.  | Ethiopia      | 194                         | Numerous                    | 104 (49.8%)                                          | *Candida krusei, Candida albicans*                                | (Seyoum et al., 2020)             |
|     |               |                             |                             |                                                      | *Candida dubliniesis, Candida albicans*                          | (Bitew and Abebaw, 2018)          |
| 2.  | Ethiopia      | 81                          | Vaginal swab                | 51 (58.6%)                                           | *Candida albicans, Candida tropicalis*                           | (Sida et al., 2017)               |
| 3.  | India         | 102                         | Numerous                    | 37 (36.3%)                                           | *Candida krusei, Candida glabrata, Candida albicans*             | (Elfeky et al., 2016)             |
| 4.  | Egypt         | 63                          | Vaginal Swab                | 38 (60.3%)                                           | *Candida albicans, Candida tropicalis*                           | (Kaur et al., 2016)               |
| 5.  | India         | 90                          | Numerous                    | 33 (36.7%)                                           | *Candida tropicalis, Candida glabrata, Candida albicans*         | (Das et al., 2016)                |
| 6.  | India         | 90                          | Numerous                    | 33 (36.7%)                                           | *Candida tropicalis, Candida parapsilosis, Candida albicans*     |                                   |
| 7.  | Brazil        | 103                         | Oral (HIV patients)         | 80 (77.8%)                                           | *Candida tropicalis, Candida parapsilosis, Candida albicans*     | (Muadheingka and Tantivitayakul, 2015) |
| 8.  | Thailand      | 250                         | Oral Cavity                 | 154 (61.6%)                                          | *Candida tropicalis, Candida glabrata, Candida albicans*         | (Mulu et al., 2013)               |
| 9.  | Ethiopia      | 177                         | Oral (HIV patients)         | 139 (78.5%)                                          | *Candida tropicalis, Candida glabrata, Candida albicans*         |                                   |
| 10. | Germany and Austria | 1062                   | Numerous                    | 573 (54.0%)                                          | *Candida glabrata, Candida parapsilosis, Candida albicans*       | (Schmalreck et al., 2012)         |
| 11. | India         | 111                         | Numerous                    | 44 (39.6%)                                           | *Candida tropicalis, Candida parapsilosis, Candida albicans*     | (Mohandas and Balla, 2011)        |
| 12. | Iran          | 428                         | Numerous                    | 273 (63.8%)                                          | *Candida parapsilosis, Candida tropicalis, Candida albicans*     | (Badiee and Alborzi, 2011)        |
| 13. | Taiwan        | 108                         | Blood                       | 61 (56.5%)                                           | *Candida tropicalis, Candida glabrata, Candida albicans*         | (Chi et al., 2011)                |
| 14. | America       | 580                         | Vaginal swab                | 420 (72.4%)                                          | *Candida parapsilosis, Candida glabrata, Candida albicans*       | (Richter et al., 2005)            |
| 15. | Latin America | 103                         | Blood                       | 43 (42.0%)                                           | *Candida parapsilosis, Candida tropicalis, Candida albicans*     | (Godoy et al., 2003)              |
Figure 1. Distribution of Candida species from the clinical specimens

Table 3. Distribution of *Candida* species from 2016 to 2020 in Istanbul, Turkey

| S/N | Isolated Candida species | 2016 | 2017 | 2018 | 2019 | 2020 | Total (%) | References |
|-----|--------------------------|------|------|------|------|------|-----------|------------|
| 1.  | *Candida guilliermondii*  | 0    | 0    | 0    | 1    | 0    | 1 (0.41)  |            |
| 2.  | *Candida kefyr*          | 1    | 2    | 1    | 0    | 0    | 4 (1.66)  |            |
| 3.  | *Candida albicans*       | 18   | 18   | 28   | 17   | 14   | 95 (39.42)| (Yardimci and Arman, 2021) |
| 4.  | *Candida dubliniensis*   | 0    | 0    | 0    | 1    | 0    | 1 (0.41)  |            |
| 5.  | *Candida parapsilosis*   | 7    | 13   | 26   | 22   | 14   | 82 (34.02)|            |
| 6.  | *Candida rugosa*         | 0    | 1    | 0    | 0    | 0    | 1 (0.41)  |            |
| 7.  | *Candida glabrata*       | 3    | 3    | 3    | 7    | 2    | 18 (7.47) |            |
| 8.  | *Candida famata*         | 0    | 1    | 1    | 0    | 1    | 3 (1.24)  |            |
| 9.  | *Candida famata*         | 1    | 4    | 5    | 5    | 2    | 17 (7.05) |            |
| 10. | *Candida lusitaniae*     | 1    | 1    | 1    | 1    | 0    | 4 (1.66)  |            |
| 11. | *Candida krusei*         | 3    | 1    | 3    | 5    | 3    | 15 (6.22) |            |
| **Total** |                  | 34 (14.1) | 44 (18.3) | 68 (28.1) | 59 (24.5) | 36 (14.9) | 241 (100) |            |
Table 4. Resistance data of Candida species from blood specimen

| S/N | Antifungal Class | Antifungal Drug | Candida tropicalis | Candida albicans | Candida parapsilosis | Candida glabrata | Reference |
|-----|------------------|----------------|-------------------|-----------------|---------------------|----------------|-----------|
| 1   | Polyene          | Amphotericin B | Austria; Norway    | United Kingdom; Austria; Spain; Norway | United Kingdom; Austria; Spain; Norway | United Kingdom; Austria; Spain; Norway | (Galia et al., 2022) |
| 2   | Echinocandin     | Anidulafungin  | Norway; Austria    | United Kingdom; Austria; Spain; Norway | United Kingdom; Austria; Spain; Norway | United Kingdom; Austria; Spain; Norway | (Galia et al., 2022) |
| 3   | Azole            | Voriconazole   | Norway; Austria    | United Kingdom; Austria; Spain; Norway | United Kingdom; Austria; Spain; Norway | United Kingdom; Austria; Spain; Norway | (Galia et al., 2022) |
|     |                  | Fluconazole    | Norway; Austria    | United Kingdom; Austria; Spain; Norway | United Kingdom; Austria; Spain; Norway | United Kingdom; Austria; Spain; Norway | (Galia et al., 2022) |
|     |                  | Posaconazole   | Austria            | United Kingdom; Austria; Spain; Norway | United Kingdom; Austria; Spain; Norway | United Kingdom; Austria; Spain; Norway | (Galia et al., 2022) |
|     |                  | Itraconazole   | Austria            | Spain; Austria    | Spain; Austria       | Spain; Austria | (Galia et al., 2022) |

4.0 Discussion

The most commonly reported Candida species with clinical importance in human is relatively finite. The World Health Organization (WHO) have concerned to develop a priority pathogen list for fungal ailments of public health important and to define research and development priorities to enhance innovation for new drugs, diagnostics and strategies (Galia et al., 2022). The most common clinical isolates of Candida species include Candida albicans, Candida tropicalis, Candida glabrata, Candida parapsilosis, Candida krusei, Candida dublinensis and Candida guilliermondii respectively, and was consistent to the studies conducted by Mamali et al. (2022). Mohandas and Ballal (2011) reported that 70.0% of Candida bloodstream infections were caused by biofilm-forming agents. Biofilm formation was uncommon in isolates from respiratory tract infection and urogenital infections (Marak and Dhanashree, 2018). This study is in line with the Institute of Health in the United States, reported that biofilms are significantly responsible either directly or indirectly for more than 80% of all microbial infections (Nobile and Johnson, 2015). However, studies related to Candida associated biofilm infections differs apparently due to the number of Candida isolates in the studies, inadequate differentiation between Candida species, quantification methodologies and diversity of the biofilm detection (Lagunes and Rello, 2016). High mortality rate was reported in Candida infections caused by biofilm formation when compared to planktonic infections and the result agreed to the current study that reports mortality rate due to biofilm associated infections. Tsay et al. (2020) revealed the effect of antifungal resistance and biofilm formation as a major risk factors among critical ill patients. This study reported a mortality rate ranged from 6.9% to 70.0% and biofilm formation varied greatly from 27.2% to 100% which is consistent with the studies reported by Ghrenassia et al. (2019). The potential ability to establish biofilms among Candida species is an important virulence factor resulting to critical infection in patients (Silver et al., 2017). Rajendran et al. (2022) reports that Candida albicans is the most predominant Candida species across the globe, being responsible for the most of systemic candidiasis and oral infections which is in agreement with this study. Silva et al. (2017) shows that Candida tropicalis demonstrated high biofilm-forming ability related to infections in ulcerative colitis, prosthetic joints and endodontic issues which is not consistent to current findings. Some studies reported that the matrix material extracted from the biofilms of Candida albicans and Candida tropicalis composed of uronic acid, carbohydrate, phosphorus, proteins and hexosamine (Silva et al., 2012). Guinea (2014) reported that the most predominant Candida species are Candida albicans, Candida glabrata and Candida tropicalis.
Parapsilosis which is agreed to this study. Studies from Brazil and Spain reported high prevalence of Candida parapsilosis and USA and Northern Europe demonstrated high prevalence of Candida glabrata. In general population, studies reported that fungal infection caused by Candida tropicalis and Candida parapsilosis are increasing concomitantly. Regardless of the geographical locations, individual immune system and antifungal therapy have a significant effect on the frequency and distribution of Candida species. Fungal infections caused by Candida glabrata is more common in old aged people whereas Candida albicans is more common among teenagers. The horizontal transmission of clinical isolates of Candida species can potentially influence the species distribution. Candida krusei is the causative agent of numerous mucosal infections and pneumonia (Atienza-Carrera et al., 2022). Candida glabrata is commonly related with infections among patients with non-healing surgical wounds, total parenteral nutrition, ventilator associated and periodontal disease (Rodrigue et al., 2014). The biofilm formation of Candida glabrata are well-structured on multilayers of blastospores with high cohesion compared to other Candida species (Silva et al., 2012). Galia et al., (2022) reported some countries such as United Kingdom, Austria, Spain and Norway that integrate antifungal resistance profile for Candida bloodstream infection in their surveillance systems at the European level. However, Spain included their resistance profile under the surveillance of health care associated infection in intensive care unit, and Austria, United Kingdom and Norway reported their antifungal resistance profile under the surveillance system for invasive fungal infection which is in line with current study. The remaining countries did not report any profile data on Candida resistance of infections (Galia et al., 2022). Regarding the Candida species within the surveillance among four reported countries providing resistance profile, Candida albicans was the most prevalent species observed including Candida glabrata and Candida parapsilosis. However, Norway and Austria reported resistance profile of Candida tropicalis. No any reports on resistance profile data on other Candida species. Amphotericin B, fluconazole and voriconazole are the most commonly evaluated antifungals agents. Amphotericin B, fluconazole and voriconazole in Candida glabrata, Candida parapsilosis and Candida albicans are the most common species drug combination agents usually evaluated in national surveillance studies. However, some Candida species like Candida auris is not mentioned in any surveillance network across the Europe. The mucocutaneous preference of antifungal resistant of Candida species in patients treated with systemic antifungals for invasive fungal infections has already been reported (Jensen et al., 2015). Galia et al. (2022) reported that an early implementation protocol on invasive candidemia caused by Candida species, developed by the Global Antimicrobial Resistance Surveillance System of Fungal Antimicrobial Resistance.

5.0 Conclusion

More research is urgently needed about the biofilm-forming ability among Candida species. High mortality rate was reported from different studies due to complications of Candida infections, caused by biofilm-forming strains. The mortality rate of invasive candidiasis remains high despite new antifungal agents and recent advances in an antifungal treatments. However, Candida species isolates vary in their potential ability to form biofilms and can be categorized according to biomass production. Multiple antifungal resistance among Candida infections has become a serious public health challenge, leading to expensive cost and clinical complications. A preponderance of Candida albicans compared with other Candida species varies between countries. Candida albicans was the most commonly isolated yeast in this study followed by other Candida species. The incidence and distribution of Candida species vary geographically and among different age groups, populations, hospital units, study periods and types of hospitals. Few countries integrate antifungal resistance profiles for Candida infections in their surveillance system. Regular reporting of Candida species distribution would help in better understanding the different epidemiological patterns between Candida species. It would be important to implement a module reporting profiles for resistance to antifungal drugs in Candida infections within existing surveillance systems for antibiotic resistance.

Declarations

Ethics approval and consent to participate
Not Applicable

Availability of data and material
Not Applicable.

Competing interests
Author declare no competing interests.

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