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Research Paper

Fungal disease incidence and prevalence in Iraq – Preliminary estimates

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ABSTRACT

Background: The surveillance of serious and superficial skin fungal infections in Iraq has not been conducted. Limited information exists on their incidence and prevalence.
Objectives: This study aimed to analyze, compute and estimate the prevalence and burden of fungal infections, as no previous data is available and no studies has been attempted in Iraq.
Methods: In the present study the data were collected and reviewed from published data on epidemiology of fungal infections nationally, internationally, from unpublished postgraduate master and PhD theses, hospital records and private clinic records. External sources of data from other countries were used for diseases which lacked sufficient local data.
Results: We estimated 985,628 annual serious infections comprising of 2.26 % of the total population. When including superficial fungal infections group of the skin, this rises to 2,075,113 infections at 4.76 % of the total population. The most common serious and skin infections were recurrent *Candida* vaginitis, fungal rhinosinusitis and tinea capitis comprising 61.5 %, 21.8 %, and 22.4 % of all infections although the total incidence of superficial fungal infections was also high at 1,071,485. Respiratory fungal disease is also common comprising 14.0 % of infections. We predicted the following annual burden per 100,000; oral candidiasis at 247.9, esophageal candidiasis at 6.04, candidemia at 5.0, *Candida* peritonitis at 0.75, recurrent *Candida* vaginitis at 5461, allergic bronchopulmonary aspergillosis at 35, severe asthma with fungal sensitisation at 46, invasive aspergillosis at 7.9, chronic pulmonary aspergillosis at 11.7, chronic fungal rhinosinusitis at 496, mucormycosis at 0.99, fungal keratitis at 14.0, and total dermatophytosis at 1631, the most severe being tinea capitis at 366. Many of these estimates were made with data sourced from other nations, so additional data from Iraq is required to validate or modify these estimates.
Conclusion: Recurrent *Candida* vaginitis, fungal rhinosinusitis, and tinea capitis are considered to be the most frequent fungal diseases present in Iraq.

Introduction

The surveillance of infectious bacteria and viruses is a widely adopted practice with multiple initiatives endorsed by national and global health organisations and currently ongoing. In contrast, the surveillance of infectious fungi and fungal disease has not been subject to the same scrutiny. Only two fungal diseases are notifiable and required to be reported to the Centers for Disease Control and Prevention (CDC) in the USA (coccidioidomycosis (Valley fever), and clinical cases of *Candida auris* infection), although some states also require notification of other fungal diseases, such as blastomycosis [1]. Just recently, India required notification of mucormycosis complicating COVID-19 patients. Some voluntary (passive) reporting schemes also exist, as for candidaemia in the UK and South Africa. Partly as a result, significant gaps in our current knowledge of the epidemiology of fungal disease persist.

Human disease due to fungi is relatively commonplace and affects >1 billion individuals worldwide. A recent estimate of severe fungal infection which can be fatal estimated a global annual incidence of 6.5 million, resulting in 3.8 million deaths annually and about 2.5

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Table 1
Underlying disease prevalence or annual incidence in Iraq in the year indicated.

Disorders	Number of cases	Years	Source
HIV	4000 prevalent cases	2023	[16,17]
HIV patients at risk of fungal disease	708 annual prevalent cases	2023	[16,17]
Pulmonary TB	5502 annual incident cases	2018, 2023	[23,24]
COPD	2346,460 prevalence, of whom 246,378 are admitted to hospital annually	2012, 2018	[15,19,22,25–27]
Asthma	1100,529 prevalence of whom 605,291 are in adults	2018, 2019	[20,21,27]
Leukemia	2027 annual incidence	2020	[28]
Acute myeloid leukaemia	466 annual incidence	2020, 2024	[2,28]
Lung cancer	2927 annual incidence	2020	[28]
Transplants in 2022	1085 kidney 32 allogeneic HSCT 10 liver	2016, 2022	[29,30]

COPD = chronic obstructive pulmonary disease, HSCT = haematopoetic stem cell transplant.

million were attributable directly [2]. Immunosuppressed individuals, those with chronic lung disease, diabetes and in intensive care are at particular risk. An estimated 47 % of all HIV mortality occurs due to fungal infections [3].

Co-morbidities are a significant aggravating factor in both the severity of fungal infections and outcomes. For example, diabetics suffer a significant increased incidence of serious and superficial *Candida* infections and mucormycosis due to the nature of the disease [4]. With an estimated global diabetes prevalence of 451 million and rising [4], the frequency and burden of such infections is going to increase and will affect such individuals in all elements and situations of their healthcare. Patients with chronic obstructive airways disease (COPD) are at direct risk of dying of invasive aspergillosis [5] and it also contributes to death in those with leukaemia and lung cancer [2].

Despite increasing appreciation of the risk of fungal disease, adequate screening, diagnosis, and surveillance remain deficient and priorities are often focused on disease entities. Emergence of antifungal resistance may be perpetrated by inadequate dosing of antifungals and lack of effective diagnosis. A publication by the CDC highlights this concerning progression with emphasis placed on *Candida* species [6], the second largest cause of fungal infections worldwide [2].

Fungal epidemiology efforts have gathered pace recently and many recent estimates performed at both a national and global scope have been published and have highlighted the concern [5,7–10] and 85 individual country estimates of fungal disease (GAFFI). A disparity exists between the availability of data in developed countries and developing countries but an overall deficiency of incidence and prevalence data remains. Much variation between countries and regions within large countries occur, but are not well documented in many places. As a result, the published global and national figures are not entirely accurate given diagnostic gaps and distinct factors which affect local incidence and prevalence. The incidence of each particular infection varies with socioeconomic conditions, endemicity in different geographic regions, and medical practice.

The purpose of this publication is to summarise what data on the burden of fungal infections in Iraq is known and provide a gap analysis for future work. Public health mycology [11] will provide key information to ensure success of the 'Roadmap for the diagnosis and management of fungal diseases' [12].

Methods

The estimation and data used in the present study were collected and reviewed from published data on the epidemiology of fungal infections nationally and internationally from Google Scholar, and PubMed, from unpublished postgraduate master and PhD theses, hospital records, and private clinic records and online resources such as WHO, GLOBOCAN, UNAIDS and IRODaT. We searched in the period 2005 to 2022. Keywords were burden of serious fungal infections, oral candidiasis, esophageal candidiasis, candidemia, allergic bronchopulmonary aspergillosis, severe asthma with fungal sensitization, chronic pulmonary aspergillosis and aspergilloma, invasive aspergillosis, recurrent *Candida* vaginitis (RVVC), mucormycosis cryptococcal meningitis, *Pneumocystis* pneumonia, fungal keratitis, dermatophytosis, fungal rhinosinusitis, HIV and fungal disease, pulmonary tuberculosis, leukemia, acute myeloid leukemia, lung cancer and transplantation. These data include some epidemiological studies from other countries that have a geographical environment similar to Iraq such as Iran, Egypt, Jordan, Turkey, and Tunisia. Where data from these countries were missing, we utilized high quality studies from other countries like China, Taiwan, and India.

Population data were obtained from an officially published report of the central statistical organization of the Ministry of Planning of Iraq, non-governmental organizations, the World Bank Group, and the World Health Organization (WHO) report [10,13]. Data related to the incidence of HIV/AIDS, cancer, chronic obstructive pulmonary disease (COPD), and asthma were estimated and reviewed from local publications and some regional studies from the Middle East [14–21] (Table 1). We assumed that 10.5 % of patients with COPD are admitted to hospital annually, as in Algeria [22]. From the total HIV population, only 30 % are on antiretroviral therapy, and it is assumed that the CD4 count fall to <200/mm^{3}occurs over 7 years and that 11 % of patients fail antiretroviral therapy. The data was also confirmed and supplemented by email dialogue with medical mycology professionals throughout Iraq.

Ethical statement

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. No ethical approval was required as the research in this article related to microorganisms.

Prerequisite estimations

Due to a severe deficiency in localized published data regarding fungal infections within Iraq, estimates had to be made with foreign data extrapolation.

Oral candidiasis & esophageal candidiasis

For the incidence of oral candidiasis (OC) in HIV and leukemia patients, we used data from the WHO to find the number of patients within Iraq and an Iranian study on reported cases of OC within these groups due to lack of such studies in Iraq [31–33]. To determine the rate of OC in patients with respiratory conditions we utilised only COPD and asthma populations and estimated inhaled corticosteroids

(ICS) use in these conditions. However, studies from Iran and the middle east were used to make an estimation regarding their prevalence [25–27]. We determined an approximate degree of ICS use within these patient groups using several published papers [34–37]. Using data from a Chinese meta-analysis which suggested OC incidence is 3.2 % in observational studies and 1.4 % in randomized control trials [38], we used an average at 2.3 %.

The incidence of cancer was taken from a publication by the Iraqi Ministry of Health on cancer, dated December 2015. According to this publication most of the cancer cases are admitted to hospital or treated with radiotherapy and nuclear medicine [39,40], so we assumed all were treated. A meta-analysis of the incidence of OC in cancer patients which found the incidence of OC in patients undergoing cancer therapy and post-therapy was averaged at 35.85 % [41]. We were unable to find any solid source of information regarding esophageal candidiasis (EC) in the general population, in respiratory patients, or in HIV from Iraq. The incidence of EC in HIV patients was derived from Smith and Orholm [42] and in cancer (9.5 %) from Gligorov and Samonis [43,44].

Candidemia

There were no data on the incidence of candidemia in Iraq. To circumvent this obstacle, we used an identical method to other papers in Jordan and Malaysia to estimate an annual incidence in the population and decided on an existing estimate of the average rate of 5/100,000 [45,46]. There were no data on the incidence of candidemia in cancer patients in Iraq therefore we used we used studies from Taiwan and China which presented a rate of 0.34 – 5.84 /1000 cancer admissions [47,48].

We used a study from Iran to determine the incidence of candidemia in HIV patients. The actual prevalence was 2.5 % over a two-year period and as such this would equate to 1.25 % annual incidence [49].

Allergic bronchopulmonary aspergillosis (ABPA)

There were no data on the incidence of ABPA complicating asthma in Iraq. We derived our estimate of incidence from two review papers which estimated a range of incidence between 1 % to 2 % and 0.7 to 3.5 % in adult asthmatics [50,51]. We used the overall average of 2.5 % in our estimations.

Severe asthma with fungal sensitisation (SAFS)

There were no published data for SAFS in Iraq. To make a prevalence estimate we used two research papers on the average incidence of severe asthma within the asthma patient group and an estimate for the incidence of SAFS within this sub-group. The authors suggested asthmatics WHO qualify as having severe asthma range between 5 % to 10 % the total patient group [52] and a 33 % incidence of SAFS in patients with severe asthma [53]. For the purpose of this study, we used an average of 7.5 % prevalence of severe asthma among all adult asthmatics.

Chronic pulmonary aspergillosis (CPA)

CPA almost exclusively occurs in individuals with pre-existing lung cavities (such as tuberculosis, non-tuberculous mycobacterial lung disease and fibrocystic sarcoidosis) or bullous lung disease but other causes include ABPA, COPD, pneumothorax, prior treated lung cancer, rheumatoid arthritis and SAFS [54]. We used 2022 WHO data on the incidence of pulmonary tuberculosis (TB) in Iraq. The WHO estimated an annual incidence of 23/100,000, equating to almost 10,000 yearly cases, and about 5500 pulmonary cases. We estimated CPA using the assumptions from multiple countries used to calculate incidence and 5-year period prevalence in India [55]. Given the relatively small number of pulmonary TB cases in Iraq, and a substantial fall in cases over the last few years, we assumed these calculations captured 80 % of all CPA cases, as they include clinically diagnosed cases mistakenly diagnosed as pulmonary TB.

Invasive aspergillosis

The estimation of the annual incidence of invasive aspergillosis (IA) was supported by published data and unpublished hospital records data within Iraq. We assumed 1.3 % of COPD patients who were hospitalised were diagnosed with IA [5], and 2.6 % of lung cancer patients [56–58]. We also assumed that 15 % of those with acute myeloid leukaemia were affected as mould-active prophylaxis is rarely used, and double the number of cases in all other leukaemia, lymphoma and multiple myeloma patients [59–61].

Mucormycosis

There were data available on the incidence of mucormycosis in patients with cancer which we used as well as that in diabetes. According the International Diabetes Federation, diabetes has a high prevalence in Iraq - an estimated 7.5 % prevalence [62,63]. Furthermore, a 12-year prevalence of 0.15 % of rhino-orbital mucormycosis of a diabetic cohort was measured [64]. We then calculated an annual incidence of 0.0125 % of mucormycosis in diabetic patients which we used for our estimations, and assumed that diabetes was the underlying disorder in 80 % of cases [65].

Cryptococcal meningitis (CM)

There were no data available on the incidence of CM within any patient groups within Iraq, therefore we used global estimates cryptococcal meningitis in HIV-infected individuals, an average global cryptococcal antigenaemia prevalence of 6 % among people with a CD4 cell count of <100 cells per μL [66]. One paper found, after completion of 24 months on anti-retroviral drugs, a virological failure incidence of 5·3 % occurred. In this study we defined virological failure as a drop of the CD4 cell count to <100 cells per μL. Moreoveranother study from Algéria estimated the prevalence of neuromeningeal cryptococcosis in HIV cases was approximately 4.2 % [67]. Another study conducted by Kilani detected the incidence of neuromeningeal cryptococcosis at 3.47 %; in addition to that, they revealed the cryptococcosis with HIV cases was 41.7 %, and the mean of CD4 cell count was 62/mm^3 [18]. To this, we added an additional 20 % for non-immunocompromised patients and 34 % for other immunocompromised patients, notably transplant recipients [68].

Pneumocystis pneumonia

To account for different annual incidence in all patient groups we considered utilizing the average global estimate of 5.79 / 100,000[7] resulting in an incidence of 2142. But this estimate is probably too high especially considering neighboring countries with both larger prevalence of HIV, cancer and a total population, such as Turkey and Iran, had estimated incidences much lower at 632 [68] and 900 cases [69] respectively. Thus, with regard to the Iraqi context we assumed a conservative 15 % annual rate of patients with newly presenting HIV patients and those with low CD4 counts develop *Pneumocystis* pneumonia and an equal number of other immunocompromised patients, a calculated annual incidence of 0.5 per 100,000.

Fungal keratitis

We used the figure of 14/100,000 from Egypt to estimate the annual incidence of fungal keratitis [70].

Table 2
Infection burden per underlying disorders in Iraq.

Infection	Number of infections per underlying disorder per year					Total Burden	Rate /100K
	None / Other	HIV/AIDS	Respiratory	Cancer/Tx	ICU		
Oral candidiasis	–	319	98,547	9059	–	107,925	247.9
Oesophageal candidiasis	–	202	–	2426	–	2628	6.04
Candidemia	–	–	–	1524	653	2177	5.0
Candida peritonitis	–	–	–	–	327	327	0.75
Recurrent *Candida* vaginitis (>4x/year)	606,322	–	–	–	–	606,322	5461*
ABPA	–	–	15,132	–	–	15,132	35
SAFS	–	–	19,975	–	–	19,975	46
Invasive aspergillosis	–	–	76	154	3203	3433	7.9
Chronic pulmonary aspergillosis	–	–	5100	–	–	5100	11.7
Mucormycosis	345	–	–	87	–	432	0.99
Fungal keratitis	6095	–	–	–	–	6095	14.0
Cryptococcal meningitis	6	32	–	9	–	47	0.11
Pneumocystis pneumonia	–	106	–	–	–	106	0.24
Fungal rhinosinusitis	215,927	–	–	–	–	215,927	496
Total burden estimated	835,181	658	138,830	13,262	4182	985,628	

ABPA = allergic bronchopulmonary aspergillosis, SAFS = severe asthma with fungal sensitisation.

Dermatophytosis

We used three research papers pertaining to the prevalence and categorization of dermatophytosis within Iraq. Their data suggested a 26 % prevalence of skin disorders within Iraq [71], and fungal infections comprise 9.9 % of skin disorders [72]. We also compared and found the average total incidences of dermatophytosis sub-categories. Other studies found that skin candidiasis comprised an average of 21.1 % of all fungal skin infections [73,74], so additional to dermatophyte infections.

Fungal rhinosinusitis

Rhinosinusitis has been studied recently in different parts of Iraq [75–77]. However, no robust data on the incidence of fungal rhinosinusitis are available to date. Based on international data, the prevalence of chronic rhinosinusitis (CRS) is probably about 10 % of the population [78–80]. Fungal rhinosinusitis in its various forms comprises around 60 % of total cases of chronic rhinosinusitis [76,77,81].

Results

Iraq is a Middle Eastern country with its population from different ethnic and national backgrounds. The population is ≈39.3 million, with approximately half males. About 3 % individuals are above 65 years old, whereas children under 14 comprise a high (38 %) proportion of the population [82]. Some of the well-established medical conditions linked to fungal disease in Iraq are listed in Table 1, including HIV, pulmonary tuberculosis (PTB), COPD, asthma, leukemia, and transplant cases.

Table 2 shows the burden of fungal disease per underlying disorders annually in Iraq, and Fig. 1 shows the type of infection incidence burden in Iraq. Among susceptible patients, we found the largest patient group was those with respiratory fungal disease (n = 138,830) followed by cancer, critical care/major surgery and other immunocompromised patients. Among transplant and cancer patients, 13,262 are predicted to be affected, many with oral candidiasis. The numbers affected annually with life-threatening fungal infection in intensive care (including invasive aspergillosis in COPD, but not influenza or Covid-19) was estimated at 4182. In HIV/AIDS patients 658 cases were assumed to have a fungal infection. Fig. 2 shows annual estimated incidence of serious fungal disease by major underlying risk group. In addition, those with a fungal disease but with no underlying condition cases numbered 835,181 cases in Iraq, mostly RVVC and fungal rhinosinusitis. Dermatophytosis is addressed separately below.

Females only (22,205,751) *; ABPA = allergic bronchopulmonary aspergillosis; SAFS = severe asthma with fungal sensitisation.

Oral Candidiasis and Esophageal Candidiasis: Oral candidiasis (OC), also known as oral thrush, occurs principally in those with HIV infection, users of inhaled steroids and cancer patients with chemotherapy or radiotherapy to the head and neck. With a low HIV burden, OC incidence is dominated by other patient groups. Using data on the estimated prevalence of asthma in Iraq, and the prevalence of asthma and COPD in Iran [25,27], we assumed between 59 % to 70 % of patients with COPD used an ICS, and 13.7 % of asthmatics used ICS [25,35]. A meta-analysis of the incidence of OC in cancer patients which found the incidence of OC in patient undergoing cancer therapy and post-therapy was averaged at 35.9 % [83]. The annual incidence of OC in the HIV positive populace was estimated at 319, and in respiratory and cancer cases were ∼98,547 and ∼9059 respectively. The incidence of esophageal candidiasis was estimated at 202 in the HIV positive populace. Assuming an annual incidence of esophageal candidiasis at 9.5 % in these patients [43], the incidence of esophageal candidiasis was estimated at 2426 in cancer patients. The total incidence of OC was determined to be 247.9/100,000 and esophageal candidiasis at 6/100,000 (Table 2), which could be an underestimate.

Candidemia and invasive candidiasis: The estimation of candidaemia in the whole population was performed using a general rate of 5 per 100,000 resulting in an incidence of 2177 cases. The incidence of candidaemia in ICU patients was derived from unpublished postgraduate research papers and listed 653 cases. Post-surgical *Candida* peritonitis comprised 50 % of ICU candidemias.

To determine the frequency of candidaemia in cancer patients we used an incidence range of 0.34 – 5.84 /1000 cancer admissions [47,48]. Using the average and the number of new cancer patients in Iraq as described by the Iraqi Ministry of Health, this would indicate a yearly incidence of 1524 cases of candidaemia in the cancer patient group (Table 2). We assumed a 1.25 % annual incidence of candidaemia in HIV-positive individuals [49]. Candidaemia is documented in approximately 40 % of cases of invasive candidiasis [2,84].

ABPA: There are nearly a million asthma sufferers within Iraq [20], and ∼55 % are adults, with the preponderance over the age of 40 years. Based on published reviews of ABPA literature, we assumed an incidence averaging 2.5 % in adult asthmatics [50,51]. This corresponds to a prevalence of 15,132 cases of ABPA (35/100,000) (Table 2).

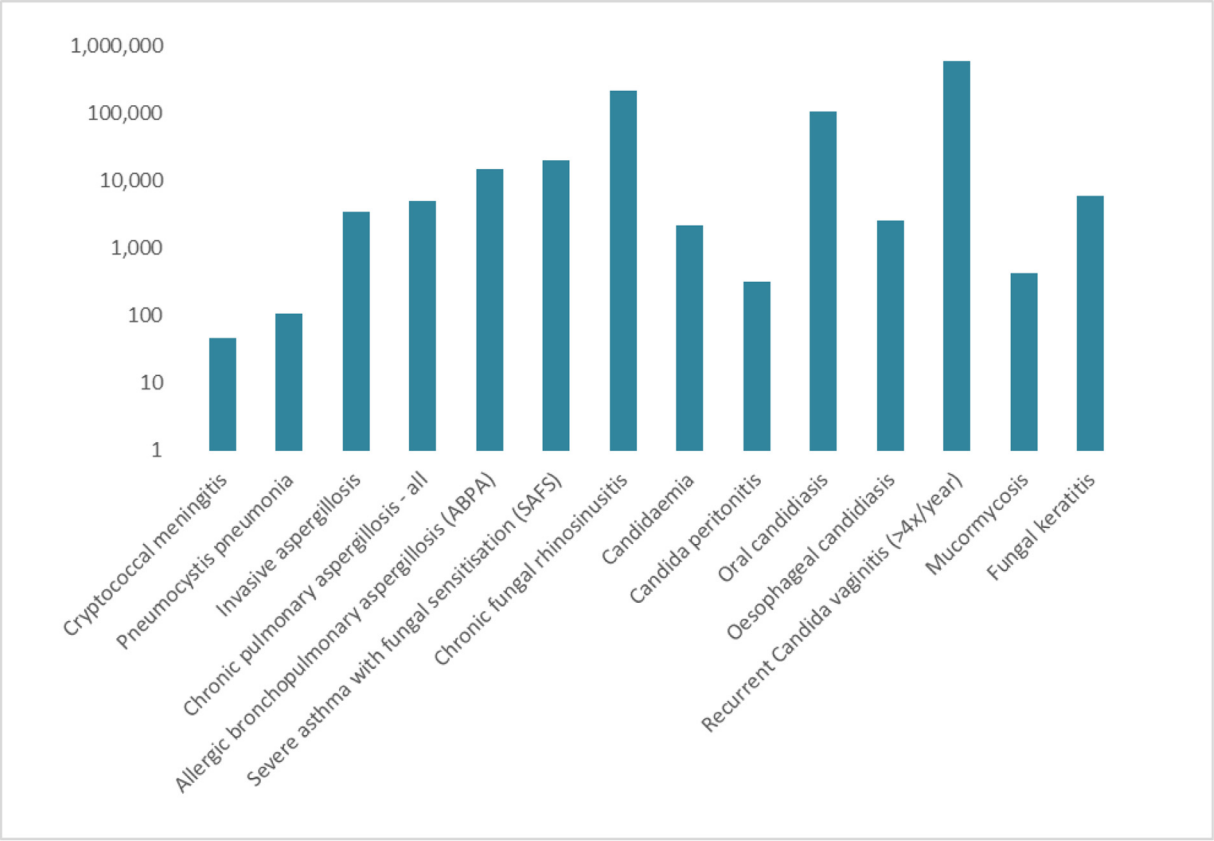

Fig. 1. Fungal disease incidence and prevalence in Iraq.

SAFS: Using an estimated proportion 10 % of adult asthmatics who qualify as having severe asthma and an estimated 33 % incidence of SAFS in patients with severe asthma [53], we determined an incidence SAFS of 19,975 individuals (46/100,000) (Table 2). There may be some duplication between ABPA and SAFS, as some ABPA patients have severe asthma, and some SAFS patients are sensitised to *Aspergillus*.

CPA: We calculated an annual incidence of 1217 cases in newly presenting patients and an additional 311 new annual cases of CPA in those cured of TB in previous 2–5 years. Probably about 156 patients die of CPA (many thought to die of TB) annually, so the overall prevalence is 5100 patients. Probably an additional 20 % of cases are positively diagnosed with CPA without a history of pulmonary TB and given the overall chronicity of disease the likely prevalence is 5100 cases (11.7/100,000).

Invasive aspergillosis: We estimate 3443 cases of invasive aspergillosis in hospitals in Iraq. A total of 154 of these cases probably occur in patients with hematological malignancy, approximately 4.5 % of the total. The remaining cases occurred mostly in lung cancer patients and those with COPD; we have not estimated general intensive care unit patients, or those with severe influenza of Covid-19. The total estimated annual incidence of invasive aspergillosis in Iraq is therefore 7.9/100,000 (Table 2).

Mucormycosis: Using an estimated 7.43 % prevalence of diabetes within Iraq [85] we calculated a total of approximately 2.7 million diabetics. The 12-year prevalence of 0.15 % of rhino-orbital-cerebral mucormycosis in the diabetic population [86] yields an annual incidence of 345 cases (12.8/100,000). An unpublished thesis from a postgraduate study estimated with a yearly incidence of 87 in cancer patients bringing the total incidence to 432 cases (0.99/100,000) (Table 2).

Cryptococcal meningitis: Cryptococcal meningitis is probably very rare in Iraq and an annual incidence 47 cases (0.11/100,000), with 32 cases annually in HIV patients, 9 cases of cancer and immunocompromised and six cases in previously well people (Table 2).

Pneumocystis pneumonia: Most cases of *Pneumocystis* pneumonia occur in severely immunocompromised patients, including AIDS, with an annual incidence of 106 cases (0.24/100,000) (Table 2). An unpublished postgraduate article reviewing hospital records estimated an annual incidence of one case every 2 years in HIV-positive individuals from more than one institution. Without data on diagnosis in other disease states, our current estimate for the rate is very low but likely to be higher in reality. The incidence of HIV cases in Iraq is very low [87], in addition, the Iraqi government utilized some strategies to prevent pneumococcal infection, a common alternative diagnosis in HIV patients [88].

Fungal keratitis (FK): We deduced the annual incidence of fungal keratitis in the general population is 6096 cases (14/100,000) (Table 2). We found three studies conducted at the Ibn-Haytham Teaching eye hospital in Baghdad regarding keratitis [89–91]. Each study had stated the number of patients positively identified with FK over a one or two-year period. We calculated the average yearly incidence within the three hospitals to be 60 cases. These studies were from Ibn-Haytham Hospital which primarily serves residents of Baghdad, the population of which is in the region of 7.5 million. There are numerous healthcare providers in Baghdad and any other reported cases outside the Ibn-Haytham Hospital are unavailable [89–91]. A large proportion of Iraq's population are involved in the agricultural sector which increases the risk of such infections and our estimate is based on data from the capital city which has a lower number of agricultural employees. There is a high possibility the incidence rate is much higher.

Dermatophytosis: In patients with identified ringworm, tinea corporis was the predominant infection in patients followed by tinea capitis (Fig. 3) [73,92,93]. Other studies also found cutaneous candidiasis comprised an average of 21.1 % of fungal skin infections [72,94].

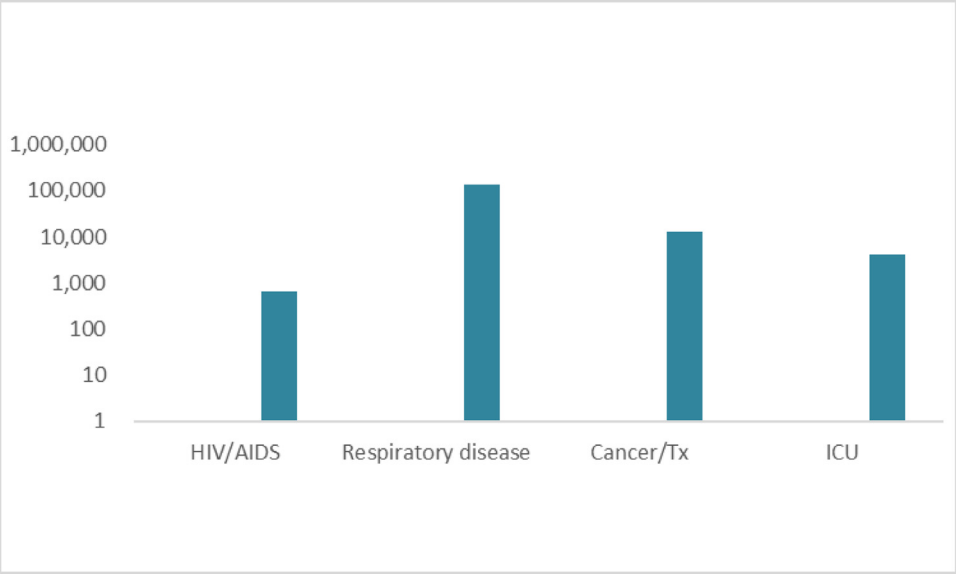

Fig. 2. Annual estimated incidence of serious fungal disease by major underlying risk group. ICU = intensive care unit. Tx = transplantion

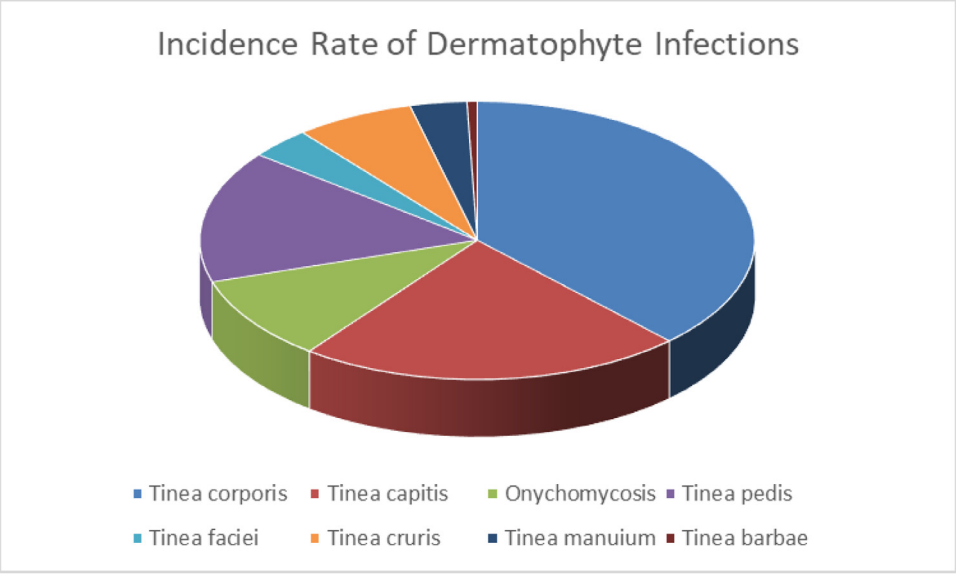

Fig. 3. Comparison of the annual incidence of different patterns of dermatophyte infection.

Using an estimated 26.8 % prevalence of skin disorders in the Iraqi population [95] and an estimate of 9.9 % of all skin diseases having a fungal basis [72], we calculate an incidence of 1071,485 superficial fungal infections of the skin. Of these same infections 57 % were caused by dermatophytes which would be equivalent to 608,892 cases, with tinea corporis and tinea capitis comprising 37.8 % and 22.4 % or 230,589 cases (619/100,000) and 136,670 cases (366/100,000) annually, respectively (Table 3), (Fig. 3). Assuming a skin candidiasis incidence of 21.0 %, 225,398 cases of skin candidiasis occur annually (608.8/100,000).

Recurrent Candida vulvovaginitis:

Vulvovaginal thrush is the most frequently diagnosed fungal infection in women and recurrent episodes in any given year are estimated to affect 6 % of women of child bearing age (15–49 years). Currently in Iraq there are approximately 10.9 million women within this group [96]. Our current estimate for the annual incidence is 606,322 women. This is equivalent to a prevalence of 5461/100,000 females yearly.

Fungal rhinosinusitis: Chronic rhinosinusitis is a fairly common complaint. CRF often occurs concomitantly with patients with atopy and asthma. There is a strong link between CRF, allergic rhinosinusitis and the prevalence and severity of asthma [97,98]. Two different phenotypes of severe asthma, the first one was severe asthma with nasal polyposis present between 13.7–20.0 % of cases and severe asthma with sensitization to molds, especially, to *Aspergillus,* common in those with severe asthma [99]. We assumed an incidence of CRF of 8 % in adults and an incidence of fungal rhinosinusitis in 10 % of individuals with CRF [100], a prevalence of 215,927. This figure includes maxillary and sphenoid fungal balls and the uncommon chronic granulomatous and invasive rhinosinusitis.

Discussion

Until recently, the burden of fungal infections has suffered from a lack of attention. The scarcity of research on fungal infections within Iraq has made any estimation difficult. The most notable observation

Table 3
Annual incident rate of dermatophyte infections.

Dermatophyte Infections	Fraction				Annual Cases	Rate Per 100,000
	Study 1 (%) [47]	Study 2 (%) [48]	Study 3 (%) [49]	Average (%)		
Tinea corporis (ringworm)	41.5	42.73	23.7	37.87	230,589	619
Tinea capitis	24.5	17.27	22.2	22.44	136,670	366
Onychomycosis	3.5	10.91	13.6	9.82	59,842	160
Tinea pedis	21	10.91	12	15.40	93,812	252
Tinea faciei	1	3.63	5.6	3.584	21,856	58
Tinea cruris	6	9.1	4.7	6.94	42,302	113
Tinea manuum	2	5.45	2	3.31	20,189	54
Tinea barbae	0.5	0	1.2	0.59	3632	9
				Total	608,892	1631

Table 4
Annual incident rate of serious fungal infections in some Middle East countries.

Infection	Infection Annual Incidence Rate (*x*/100,000)				
	Iraq	Iran	Turkey	Jordan	Egypt
Oral candidiasis	247.9	–	6	0.14	2.73
Esophageal candidiasis	6.04	6.1	0.76	1	0.85
Candidemia	5	0.34	4.76	5	5
Candida peritonitis	0.75	-	0.8	0.75	0.79
Recurrent *Candida* vaginitis (>4x/year)	5461	9280	3342	3079	3169
Allergic bronchopulmonary aspergillosis (ABPA)	35	48.2	40	141	162
Severe asthma with fungal sensitisation (SAFS)	46	63.7	53	186	214
Invasive aspergillosis	7.9	8.03[a]	4.84	1.34	10.7[b]
Chronic pulmonary aspergillosis	11.7	1.6	7.29	11	13.8
Mucormycosis	0.20	9.2	–	0.02	-
Cryptococcal meningitis	0.11	0.14[c]	0.13	0	~0
Pneumocystis pneumonia	0.24	-	0.79	0.1	0.15
Tinea capitis	366	3194	54	–	-

[a] IA in COPD used;.
[b] Likely to be higher given lack of documentation;.
[c] Probably many more in undiagnosed HIV+ patients;.

of this study is that superficial infections comprise the majority of fungal infections within Iraq at an estimated annual incidence of 1,071,485. This is a common observation with similar conclusions in Turkey and Iran where such infections numbered in the millions (Table 4). Skin fungal infections impose a significant burden on people globally. The highest prevalence is observed in nations with few resources, tropical areas, and among children aged 1 to 5. DALYs have the potential to be a valuable tool for allocating health policy resources to enhance the worldwide effect of fungal skin disease [101]. In this study we estimated an annual incidence rate of 252/100,000 tinea pedis but in stark contrast, the study in Turkey found a rate of 2215/100,000 with a similar incidence of onychomycosis, 2139/100,000 [68]. A significant contributory factor listed in the Turkish study was the presence of the population's Muslim-majority habits concerning religious practices. It is common practice to use communal washing facilities. This can often be followed by immediately wearing occlusive footwear, both of which are known to contribute to the development of tinea pedis and onychomycosis. Iraq is also a Muslim-majority country with identical practices in the Islamic community. It is therefore very likely the true incidence of tinea pedis is much higher than our estimate and further research needs to be undertaken. No data on kerion and baldness complicating tinea capitis was found in Iraq, but is found in a significant minority elsewhere. *Trichophyton indotineae* (terbinafine resistant) has not yet been recognized in Iraq but is likely present. Tinea pedis and onychomycosis are probably significant underestimates.

The respiratory patient group suffered the greatest fungal burden of all at risk groups considered within the study. The total burden of 138,830 is dominated by oral candidiasis and fungal asthma (ABPA and SAFS). The asthma prevalence was difficult to ascertain, and so these figures may not be very precise. The prevalence of fungal asthma in Egypt and Jordan were apparently much higher because asthma rates in adults are higher (Table 4). Iraq has a very dry climate and during the summer months, significant periods of dryness and intense heat can lead to a very dusty environment which can both worsen asthma and increase the likelihood of inhaling fungal spores and increasing the severity of asthma. Another factor is the effect of smoking. Nearly every organ in the body can be harmed by tobacco use, and research has shown that cigarette smoking is an elevated risk factor for several diseases [102]. The issues with tobacco use are linked to the social and cultural context, as well as the post-traumatic stress disorder (PTSD) that some people experience after wartime situations. Iraq has a high prevalence of smokers. Smoking itself increases susceptibility to fungal infections and compounds all risks associated with asthma and COPD but the interaction between fungal asthma and smoking is not well studied [103].

COPD is relatively common in Iraq, but the precise number was taken from a mean figure for the Middle East, rather than from data generated in Iraq. A study of chronic bronchitis in smokers seeking care found 64 % to have asthma [104]. COPD and asthma may overlap. COPD is a risk factor for both IA and CPA. IA cases in COPD was estimated at a 1.3 % of those hospitalized with COPD, which is conservative as in southern China it was 3.9 % [105]. We attributed all these cases to intensive care, but realise that many may not receive such care if they have very advanced COPD.

We derived the CPA incidence and prevalence estimate from pulmonary TB cases, with an additional 25 % of cases for other underlying diseases. As TB is relatively infrequent in Iraq, but COPD common, this probably underestimates frequency.

In Lebanon and Saudi Arabia almost all recorded cases of fungal infection occurred in patients undergoing cancer therapy [106]. Approximately 30 % of the cases occurred in patients with

hematological malignancy with the remaining cases patient groups unspecified.

Chronic rhinosinusitis is common in Iraq. Using the proportion of 60 % of such cases being linked to fungal allergy/sensitization or fungal ball or granulomatous sinusitis, we estimate a prevalence of over 200,000 patients. No studies have been done on this entity in Iraq, to our knowledge. Also common is otomycosis, although we have not attempted to estimate its incidence. A single teaching hospital in Mosul saw 179 cases in 15 months in 1988–89 [107], but there are no recent data.

The rate of RVVC in Iran was much higher than we estimate for Iraq but this could be due to the Iranian study using different derivative estimations. We used a 6 % incidence in women in the appropriate age range, similarly to Egypt, whereas the Iranian study used a cross-sectional study from a central city of Iran which placed incidence within the appropriate age range at 12.3 %. Had we used the same study our estimate would have been approximately double. The high prevalence rate of RVVC in our study may be due to some factors such as disease management, symptomatology, and post-treatment outcomes [108], in addition, to other factors contributed with RVVC like poor quality of life, psychosocial impact, awareness, education, and sexual function [109,110].

Without relevant local data on the incidence of OC and esophageal candidiasis in the respiratory patient group, we used the correlation between ICS use and OC to make estimates. Our estimate of 247.9/100,000 was significantly higher than Turkey and Egypt and likely due to our different approach to reaching the estimate. As well as the development of OC, ICS can directly cause esophageal candidiasis due to their local immunosuppressive action [111]. We did not find any data within Iraq regarding the incidence of esophageal candidiasis and so our estimate may be lower than what would be empirically observed as millions of individuals within the Iraqi population use ICS.

For some estimates such as candidaemia, we used an average incidence derived from a study on the global burden of fungal infections [7]. Although we have some data on the reported cases within the ICU patient-group we decided to make further investigations to improve the overall accuracy of our estimates. Candidemia occurs in all patient groups and using the average global estimate as an end point, we subtracted the estimates for each patient group in an attempt to deduce the incidence in patient groups either not mentioned in the study or without applicable research data. Our estimated rate of *Candida* peritonitis was derived from data pertaining to reported cases in the ICU patient group [112] and is similar to the others presented in this study and ranged from 0.75/100,000 in Iraq to 0.8 in Turkey.

In burned patients, *Aspergillus* spp. and *Candida* spp. are the most common fungi found [113]. The prevalence of fungal infection was higher in individuals who had open dressing (25.5 %) than those who received occlusive dressing (16.0 %) [113]. We have not separately estimated this annual incidence.

Mucormycosis appears to be relatively common in Iraq. Our study utilized data regarding its incidence in diabetes and a single source of unpublished postgraduate research. Our estimated rate of incidence of 0.99/ 100,000 was greater than that of Jordan (0.02) but approximately 18 times less than Iran. Mucormycosis occurs in disease states other than diabetes mellitus. Organ transplantation, intravenous drug use, low birth weight infants, malnutrition, chronic alcoholism and liver diseases are also risk factors for which there are no data from Iraq [114]. Our estimate was heavily dependent on the estimate of the prevalence of diabetes within Iraq and will change according to new estimates and figures of diabetes and did not account for the other factors, for which there are no incidence data. The study in Iran also used a different source for the estimated prevalence of mucormycosis in diabetics with an estimated 0.16 % prevalence [86]. Had we used the same foundational estimate of prevalence, we would have a total of 4490 yearly cases in Iraq and an incidence rate of 12.1/100,000. In either case, the true incidence of mucormycosis is very likely to be greater but is difficult to ascertain without further research. Mucormycosis is a dangerous infection with a high mortality rate and often life-changing damage in survivors [65,114] which magnifies the burden impact not only in a healthcare perspective but socially and economically.

Antifungal drugs are essential for treating invasive fungal diseases, which, if untreated, can be fatal. In Iraq in the community, the most frequently recommended antifungal agents by pharmacists for oral candidiasis were topical miconazole and nystatin (70.3 %), followed by fluconazole and amphotericin B (11.9 %) [115]. WHO lists the following systemic antifungal agents as an essential medications: amphotericin B, fluconazole, flucytosine, griseofulvin, itraconazole, voriconazole, and one of the echinocandins (micafungin, caspofungin and anidulafungin) [116]. Of these, all are available in Iraq market as well as terbinafine and topical nystatin, isoconazole, tioconazole, luliconazole, miconazole, clotrimazole, sertaconazale, econazole, amphotericin B and ketoconazole. Some antifungal susceptibility testing has been done in Iraq, but no overall picture of antifungal resistance to modern antifungals has emerged [117,118].

Limitations statement

It is important to note that no fungal-disease specific reporting directives have been issued by the Iraqi health authorities as in the majority of countries globally. There have been few published papers on the incidence of fungal infections in Iraq and most existing papers may be out-of-date. The estimates concluded in this research combined data on the incidence of fungal infections and disease incidence or prevalence from many sources. Most countries have variances in their healthcare systems, regulations, economy, population demographics, public knowledge of health/disease and presence of conflict or disaster which can induce distinct changes to a societies disease burden not just in fungal infections but all diseases. The use of numerous ‘outside’ sources of information to make ‘inside’ estimations does diminish the precision of the estimates made. The comparative lack of available research on fungal infections in Iraq should be a stimulus for more epidemiological research on fungal disease.

Conclusion

In conclusion, *Candida* vaginitis, fungal rhinosinusitis, and tinea capitis are considered to be the most frequent fungal conditions in Iraq. These fungal diseases range from superficial thrush to life-threatening invasive infections. COPD is common in Iraq; however, precise data and sampling are required to confirm our estimated incidence of aspergillosis. Cancer and AIDS continue to increase in Iraq and demands monitoring for fungal infections. Epidemiological studies and precise records of fungal infection in Iraq is lacking, which may underestimate the seriousness of such infections. The present study is the first summary of fungal infection in Iraq. Validation and modification of these estimates will be necessary in future epidemiological work.

Declaration of competing interest

None of the authors have a conflict of interest with the contents of this manuscript

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