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ASSOCIATION OF ANTIBIOTIC RESISTANCES AMONG *MYCOBACTERIUM TUBERCULOSIS* AMONG SALAH-ALDEEN COMMUNITY

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ABSTRACT

Background: Mycobacterium tuberculosis, the etiological agent causing tuberculosis, is one of the most common contagious diseases that poses a serious threat to human health. As per the recent WHO report, TB incidence throughout the world amounts to 10.7 million and the total death cases due to tuberculosis is around 1.23 million. multidrug and extreme drug resistance TB which is around 390,000, adds to the additional burden of TB**. Materials and Methods:** This study was carried out in the Antituberculosis and Chest Diseases Center in Tikrit city. Sputa of 479 patients referred to the laboratory were examined. All patients complaining of fever, night sweat, weight loss, cough, shortness of breath and haemoptysis. Socio-demographic characters of the patients were record. Patients referred to laboratory were examined by means of X-ray. Egg-base medium, Lowenstein-Jensen medium were used for isolation of bacteria and the isolated pathogen was identified and their sensitivity to antibiotics was carried out. **Results:** The degree of association between antibiotics using low and high concentration antibiotic discs among 86 isolates of *Mycobacterium tuberculosis* was studied and the results were analyzed which showed a share resistance between pairs of antibiotics tested using low and high concentrations. The pooled association effect was substantially higher at the low antibiotic concentration (pooled Phi ≈

0.94), indicating very strong co-resistance among antibiotic pairs. **Conclusions:** The frequency of resistances were not symmetrical as determined by the considered resistance e.g. 83.3% of isolates resistant to streptomycin were resistant to isoniazid while 16.1% of isolates resistant to streptomycin were resistant to isoniazid using low concentration of antibiotic discs. The same observation was noticed as 4.1% of isolates resistant to rifampicin were resistant to streptomycin while 66.7% of isolates resistant to streptomycin were resistant to rifampicin. Data analysis shows that the degree of association between pairs of resistance to antibiotic used. The pooled effect at the high antibiotic concentration was moderate (pooled Phi ≈ 0.46), suggesting that increasing the antibiotic concentration markedly reduced the overall strength of phenotypic resistance associations. At the low concentration, the strongest associations were observed for the RMP–EMB**,** RMP–SM**,** INH–EMB**,** and SM–INH pairs, whereas the SM–EMB pair exhibited only a negligible association.

KEYWORDS: Patients, tuberculous agents, antibiotics, paired resistances, association degree**.**

INTRODUCTION

Mycobacterium tuberculosis, the etiological agent causing tuberculosis, is one of the most common contagious diseases that poses a serious threat to human health. As per the recent WHO report, TB incidence throughout the world amounts to 10.7 million and the total death cases due to tuberculosis is around 1.23 million. multidrug and extreme drug resistance TB which is around 390,000, adds to the additional burden of TB. The MDR/XDR tuberculosis is mainly due to the development of resistance by the pathogen against two powerful anti-TB drugs, i.e. isoniazid and rifampicin. The first line of anti-TB drugs, i.e. isoniazid, rifampicin, pyrazinamide, and ethambutol, are mostly effective against drug sensitive TB but ineffective against the drug-resistant strains of M. tuberculosis. Tuberculosis causes ill-health among millions of people each year and ranks as the second leading cause of death from an infectious disease worldwide.[1] TB usually affects the lungs but it can also affect other parts of the body, such as brain, intestines, kidneys, or the spine. Symptoms of TB depend on where in the body the TB bacteria are growing. In the cases of pulmonary TB, it may cause symptoms, such as chronic cough, pain in the chest, haemoptysis, weakness or fatigue, weight loss, fever, and night-sweats.[2] There are two main types of TB; one is the latent TB, which means a person carries the TB germ but is not sick and cannot pass the germ on to other people and the other type is active TB.[3] Since the discovery and use of streptomycin

for TB treatment, significant progress has been made in the development and production of anti-TB drugs, relying on the foundation for the standard 6-month therapy.[4,5] Recently, the treatment of drug-resistant TB has seen changed with the introduction of bedaquiline and delamanid, with several clinical trials which are fundamentally changing the treatment of various forms of drug-resistant *Mycobacterium tuberculosis.*[6,7,8,9,10] The treatment regimen for drug-sensitive TB still primarily consists of four drugs like isoniazid, rifampicin, pyrazinamide, and ethambutol. Researchers focused on increasing rifampicin dosage with incorporating or substituting fluoroquinolones.[11] Isoniazid-resistant TB is the most common type of drug-resistant TB.[12,13] WHO recommended fluoroquinolones for isoniazid-resistant TB and announced for the need for formal clinical research studies to evaluate the best treatment methods.[10,14,15] The incidence of rifampicin-resistant TB is increasing, with predominant form of mono-drug-resistant TB.[16] WHO recommended a 9–12 month all-oral regimen for most rifampicin- resistant TB patients, which has been revealed to improve treatment outcomes.[16,17] The treatment success rate for multiple drug resistant-TB(MDR-TB) remained below 50 % in most high-burden countries.[10] Optimizing MDR-TB treatment policy is crucial and requires consideration of patients clinical presentations and strain-specific drug sensitivity testing.[18,19] The incidence of rifampicin-resistant TB is increasing, with predominant form of mono-drug-resistant TB.[20] WHO recommended a 9–12 month all-oral regimen for most rifampicin- resistant TB patients, which has been revealed to improve treatment outcomes.[21,22] The treatment success rate for multiple drug resistant-TB(MDR-TB) remained below 50 % in most high-burden countries.[17,23] Optimizing MDR-TB treatment policy is crucial and requires consideration of patients clinical presentations and strain-specific drug sensitivity testing.[24,25] Isoniazid-resistant TB is the most common type of drug-resistant TB.[17,26] The minimal inhibitory concentration (MIC) is defined as the lowest concentration of an antimicrobial agent that prevents the growth of a microorganism under standardized incubation conditions and is typically expressed in µg/mL Clinically, the broth microdilution method usually depends on semi-quantitative measurements like inhibition of visible growth, to determine MICs.[27] MIC values for given drug and type of bacteria including mycobacteria may vary depending on the assay used, a lower MIC value consistently shows greater potency.[28,29] Iraq shows its dedication and commitment to prevent and control TB. Between 2003 and 2012, the TB case detection rate gradually and consistently increased to reach 57% which is 8, 664 TB cases in 2012. Eighty-nine per cent (89%) of infectious cases detected were successfully treated. Care for drug-resistant forms of TB was expanded and innovative partnerships were developed between the public and private

sectors, as well as with civil society, TB-affected communities, donors and media and consistently increased to reach thousands cases in 2012 particularly pulmonary type.[8] Despite appreciable progress made against TB in Iraq, there is still 43% of the total estimated number of TB cases is missed every year, leaving thousands of untreated TB patient suffering and causing the suffer to others. Other works on this disease have been carried out that showed different frequencies of incidences utilizing onsite serological rapid tests.[30] Since 1980, Iraq is passing through a series of wars that might influence the status of infectious diseases including TB.[31,32,33,34,35,36]

MATERIALS AND METHODS

Health Institute

This study was carried out in the Antituberculosis and Chest Diseases Center in Tikrit city. The goal of this study was to diagnose and treat all cases of tuberculosis. The patients included in the present study were from different towns including the city center of Tikrit of Salah-Aldeen governorate. The present study was carried out in the laboratory of this health institute according to methods previously followed by other workers.[13,19,30]

Patients

Sputa of 479 patients referred to the laboratory were examined. The ages of patients ranged from 13 to 65 years. Some patients were referred to the center from other towns' hospitals. All patients complaining of fever, night sweat, weight loss, cough, shortness of breath and haemoptysis. Socio-demographic characters of the patients were record. These characters included age, gender, occupation, education, residence, income, family history of T.B. and town of birth.

X-Ray examination

Patients referred to laboratory were examined by means of X-ray. These x-rays were examined and read by a radiologist and the results were included in the present study for comparison and conformation of the laboratory results of investigation.[14,19,22]

Isolation and identification of Mycobacterium tuberculosis

Egg-base medium, Lowenstein-Jensen medium were used for isolation of bacteria and the isolated pathogen was identified following methods described elsewhere.[17,37,38]

Susceptibility testing of Mycobacterium tuberculosis

The antibiotics susceptibility testing of M. tuberculosis was carried out following methods described by other workers.[17,24,39,40]

Statistical analyses

All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics such as means, standard deviations, and frequency distributions were computed to summarize the data. A paired sample t test correlation coefficient (R) and coefficient of determination (R2) were calculated.[41,42,43]

RESULTS

The degree of association between antibiotics using low and high concentration antibiotic discs among 86 isolates of *Mycobacterium tuberculosis* was studied and the results are listed in Table 1, which shows the share resistance between pairs of antibiotics tested using low and high concentrations. It was seen that a number of isolates resistant to pairs of antibiotics while no isolate was resistant to streptomycin -isoniazid as it was seen in the matrix data listed in the table 1. The frequency of resistances were not symmetrical as determined by the considered resistance e.g. 83.3% of isolates resistant to streptomycin were resistant to isoniazid while 16.1% of isolates resistant to streptomycin were resistant to isoniazid using low concentration of antibiotic discs. The same observation was noticed as 4.1% of isolates resistant to rifampicin were resistant to streptomycin while 66.7% of isolates resistant to streptomycin were resistant to rifampicin. Table 1 also shows the degree of association between pairs of resistance to antibiotic used. Isoniazid-rifampicin shows a strong association but other resistances appeared to stand as close to independence e.g. rifampicin with streptomycin and ethambutol using low concentration antibiotic discs. Using high concentration antibiotic discs revealed weak association as can be observed in Table 1. A random-effects meta-analysis of pairwise phenotypic antibiotic resistance associations among 86 *Mycobacterium tuberculosis* isolates revealed marked differences between low- and high-concentration antibiotic disc conditions. The pooled association effect was substantially higher at the low antibiotic concentration (pooled Phi ≈ 0.94), indicating very strong co-resistance among antibiotic pairs. In contrast, the pooled effect at the high antibiotic concentration was moderate (pooled Phi ≈ 0.46), suggesting that increasing the antibiotic concentration markedly reduced the overall strength of phenotypic resistance associations. At the low concentration, the strongest associations were observed for the RMP–EMB**,** RMP–SM**,** INH–EMB**,** and SM–INH pairs, whereas the SM–EMB pair exhibited only a negligible

association. Under the high-concentration condition, association strengths decreased considerably for most antibiotic pairs, with **only** RMP–SM**,** RMP–EMB**,** and RMP–INH maintaining moderate-to-strong relationships (Figure 1). Associations involving SM–INH**,** SM–EMB, and INH–EMB became minimal or absent. The heterogeneity analysis revealed very high between-pair variability ($I^2 > 95\%$) in both concentration groups, indicating that the magnitude of association differed substantially among antibiotic combinations. This supports the use of a random-effects model, as the observed variability reflects genuine biological differences rather than sampling error alone. Overall, the findings indicate that low antibiotic concentrations reveal strong phenotypic co-resistance patterns among *M. tuberculosis* isolates, whereas higher antibiotic concentrations substantially weaken these associations. These results suggest that antibiotic concentration plays an important role in the apparent connectivity of resistance phenotypes and may improve discrimination between truly resistant and weakly associated resistance profiles.

Table 1: Matrices showing the association between phenotypic resistance to pairs of antibiotic among 86 isolates of *Mycobacterium tuberculosis* using low and high concentrations of antibiotic discs.

Analysis	**Concentration(µg/disc):**								
Matrix	**Low concentration**					**High concentration**			
	EMP	5				1			
	INH	10	8			0	1		
	RMP	12	9	62		2	2	4	
		SM	EMB	INH		SM	EMB	INH	
Frequency		RMP	SM	EMB	INH	RMP	SM	EMB	INH
	RMP	-	14	10.5	72.1	-	4.1	4.1	8.2
	SM	100	-	14.7	83.3	66.7	-	33.3	0
	EMB	100	5.6	-	8.9	100	50	-	50
	INH	100	16.1	12.9	-	66.7	0	16.7	-
Degree of association		SM	INH	EMB		SM	INH	EMB	
	RMP	125.6	12.8	136.1		48.1	42	50.3	
	SM	-	59.3	0.1		-	0.1	0.01	
	INH	-	-	64.1		-	-	0.3	
	EMB	-	-	-		-	-	-	

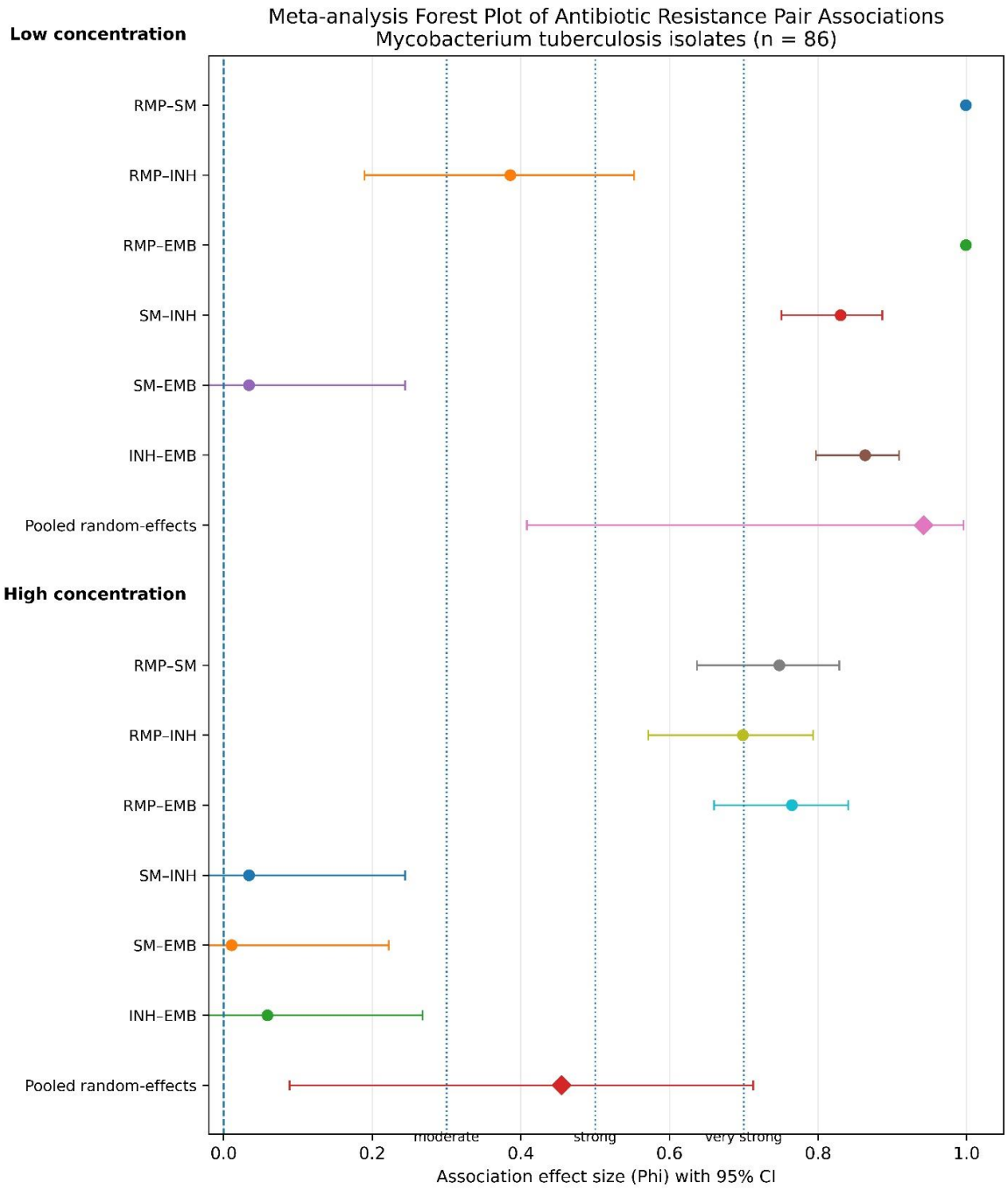

Figure 1: Forest Plot of the Meta-analysis of Pairwise Antibiotic Resistance Associations in *Mycobacterium tuberculosis.*

DISCUSSION

The degree of association between antibiotics using low and high concentration antibiotic discs among 86 isolates of *Mycobacterium tuberculosis* was studied and the results are listed in Table 1, which shows the share resistance between pairs of antibiotics tested using low and high concentrations. It was seen that a number of isolates resistant to pairs of antibiotics while no isolate was resistant to streptomycin -isoniazid as it was seen in the matrix data

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both in vitro and in vivo experimental results.[44] The combination of Isoniazid(INH), Rifampicin (RIF), and Human Neutrophil Peptide-1 (HNP-1) has been shown to decrease the minimum inhibitory concentrations(MIC) by 8-fold, leading to a substantial improvement in eradication pathogens from the liver, lungs, and spleen in infected individuals.[45,46,47,48,49,50,51] Similarly, both Protegrin-1(PG-1) and HBD-1 sharply reduced the in vitro growth of drug susceptible and multiple drug resistant (MDR) of pulmonary tuberculosis strains when combined with INH, enhancing much more effective than using the peptide or the antibiotic alone.[52,53,54] Several synthetic peptides, like granulysin-derived peptide (GranF2) have shown highly effective synergy with Ethambutol (EMB) by increasing cell-wall permeability, effectively clearing intracellular Mtb from macrophages without harming host cells [55,56,57]. Whereas NZX and its variant NZ2114 exhibit synergistic and additive effects when combined with EMB or INH, successfully decreasing bacterial total viable counts in vivo against murine TB.[58,59,60,61] Moreover, The present study revealed four different resistance patterns of antimycobacterial antibiotics among 47 isolates of *M. tuberculosis*. There were 28, 10, 8 and 1 isolate resistant to 1, 2, 3 and 4 antibiotics at the same time respectively. The frequency of sensitive isolates was 45.3% (39/86). The majority of isolates were either susceptible (45.3%) **or** resistant to a single antibiotic (32.6%)**.**However, traditional laboratory techniques for identifying MTB are still widely used in local and other developing countries because they are both feasible and trustworthy. Identifying MBT using AFB staining and fluorescence microscopy and the culturing and isolation of pulmonary tuberculosis are diagnostic approaches that allow for a more precise diagnosis of pulmonary tb than the clinical-based diagnosis. Because many of the former clinical features of PTB might be mistaken for other illnesses, such as coccidioidomycosis and Aspergillosis, in addition to a PTB clinical picture, detecting and characterizing MTB in patient sputum is necessary.[62,63,64] Precisely, for an accurate diagnosis, the clinical methods.[65,66,67,68] this study of 395 MDR/RR-TB patients demonstrates that the cohort exhibits a high proportion of pre-XDR-TB (48.4%) and a suboptimal treatment success rate (66.8%). Retreated patients show significantly elevated MICs for multiple drugs and distinct immune dysregulation characterized by decreased IL-2 and increased IL-12 levels. Strong cross-resistance exists between moxifloxacin and ofloxacin, while moderate partial cross-resistance were found between rifampicin and rifabutin and between amikacin and kanamycin. Elevated MICs for ethambutol and isoniazid were associated with treatment failure after multivariable adjustment. However, these associations did not retain statistical significance after Benjamini-Hochberg FDR correction for multiple comparisons. Therefore, these findings should be considered exploratory and

hypothesis-generating rather than conclusive evidence of independent prognostic value for quantitative MIC testing. Given the limited sample size, and the lack of adjustment for several clinically important factors including resistance category, disease severity, regimen composition, and adherence, these findings require validation in larger cohorts. If confirmed in future studies, they would suggest a potential role for considering MIC results in individualized regimen design, along with comprehensive patient support to reduce loss to follow-up in MDR/RR-TB.[69] Moreover, There were 10 different patterns of resistance to antibiotics among *M. tuberculosis* isolates which were occurred twice or more. The most frequent pattern was the resistance to ethambutol by 13 isolates harvested from T.B. patients. 5.8% (5/44) of the isolates were resistant to rifampicin and isoniazid at the same time. Multiple drug resistant-TB (MDR-TB) is resistant to at least two major first-line drugs (INH and RIF), Pre-extensively drug-resistant TB has been proved to be resistant to both drugs and fluoroquinolones (FQs), and XDR-TB is MDR-TB that is also resistant to all FQs and at least one other Group A drug like levofloxacin, moxifloxacin, bedaquiline and linezolid. MDR-TB occurred in 3.6% and 18% of new and previously treated TB cases, respectively.[69] Treatment of MDR-TB requires a long period of time which might need to use of second-line anti-TB drugs. It was found that most drugs are less effective with more side effects and are more expensive than first-line drugs.[70,71,72,73] The overall treatment success rate for MDR and XDR *M. tuberculosis* isolates was less than 60% and 40% respectively.[74,75] Treatment in TB patients is challenging given the moderate tolerability, complexity and long duration which currently available for both drug-sensitive and drug-resistant TB particularly MDR-TB.[76,77,78,79] Combinations of three or more drugs are often used and useful to treat diseases of resistant mycobacteria. Successful combinations generally result from a combination of potent synergistic drugs and non-overlapping resistance mechanisms. The effect of the combination could be differ significantly from the sum of the individual effects. The lower dose of synergistic combinations allow for to minimize high toxicity or higher doses to reduce the development of tolerance.[80,82,83,84,85,86.87] pruposed diagnosis of PTB is essential first, which should be confirmed by the laboratory-based investigations.[88,89,90]

CONCLUSIONS

The frequency of resistances were not symmetrical as determined by the considered resistance e.g. 83.3% of isolates resistant to streptomycin were resistant to isoniazid while 16.1% of isolates resistant to streptomycin were resistant to isoniazid using low concentration of antibiotic discs. The same observation was noticed as 4.1% of isolates resistant to

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Statement of Ethics

All the procedures involving human participation were conducted in strict accordance with ethical standards of Institutional Research Committee, Department of Scientific Research, Tikrit University as well as the 1964 Helsinki Declaration and its subsequent amendments or equivalent ethical norms.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest Statement

The author declares that he has no conflicts of interest, financial or otherwise.

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