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Evaluation of Discrepancy between GeneXpert (MTB/RIF) Assay and Drug-Susceptibility Test Result

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ABSTRACT

Rationale. Discrepancies between tests for drug-resistant tuberculosis infections are becoming more common as diagnostic tools become more varied. These discrepancies may partly causes the longer time to diagnose tuberculosis that leads to delay of treatment.

Objectives. The main objective was to investigate discrepancies between GeneXpert (MTB/RIF) and drug-susceptibility test in diagnosing tuberculosis drug resistance and which factors were associated with those discrepancies. Other purpose was to measure the proportion of different types of drug-resistant tuberculosis and to identify the factors affecting the occurrence of multi-drug resistant tuberculosis in Indonesia.

Methods. This was a cross-sectional study. Demographic data and clinical characteristics of patients were collected from eTB Manager of Persahabatan General Hospital from January 2015 to December 2017. We did descriptive analysis of patient characteristics, resistance pattern, and treatment outcomes. Association of patient characteristics with tests discrepancies and occurrence of multi-drug resistant tuberculosis were further analyzed.

Measurements and Main Results. Discrepancy of GeneXpert (MTB/RIF) and drug-susceptibility test were found in 48 cases (7%). Factors that significantly influenced the emergence of a discrepancy were number of previous treatments (p=0.009) and use of different sputum samples (p<0.001). Multi-drug resistant was the most prevalent type of drug resistance (35%, N=239) and was affected significantly by re-treatment cases.

Conclusions. The number of discrepancies between GeneXpert (MTB/RIF) and drug-susceptibility test was low and associated with the number of previous treatments and use of different sputum samples. Adherence to diagnosis and treatment protocol should be done to reduce tests discrepancies and re-treatment possibilities.

Keywords: Diagnosis, Tuberculosis, GeneXpert, MDR Tuberculosis.

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INTRODUCTION

Despite the fact that tuberculosis can have a timely diagnosis, proper treatment, and be cured, the epidemic of tuberculosis and multi-drug resistant tuberculosis remains a high burden in more than thirty countries. Tuberculosis is one of the top ten causes of death worldwide, where over 4,000 children and adults die each day due to lack of diagnosis, lack of quality care, or drug resistance. In 2015, there were 1.4 million tuberculosis deaths globally. India, Indonesia, and China made up nearly half of the tuberculosis cases in the world.[1-3]

Multi-drug resistant tuberculosis is when the patient resistant to both rifampicin and isoniazid. World Health Organization estimated 580,000 (range of 520,000-640,000) incidence cases of multi-drug resistant tuberculosis globally in 2015. About 9.5% of multi-drug resistant tuberculosis cases were extremely drug resistant tuberculosis which is defined by resistant to rifampicin, isoniazid, a fluoroquinolone, and a second-line injectable agent. By 2016, extremely drug resistant tuberculosis was reported in over one-hundred countries worldwide.[1-3]

Around 40% of people with tuberculosis do not receive a diagnosis or are unreported. Some patients face multiple healthcare visits and lengthy delays before obtaining a diagnosis. The average time of first contact with health care provider to diagnosis is 28 to 30 days, even when the patient presents with overt tuberculosis symptoms.[2,4] Additionally, too few or improper drug-susceptibility testing has led to nearly a quarter of patients to be diagnosed with drug-sensitive tuberculosis when in fact they have a drug-resistant strain of tuberculosis.

Due to the advancement of laboratory technologies, there are more specific, sensitive, and rapid diagnostic modalities. However, the results may be conflicting between various tests. Discrepancies between diagnostic tests for drug-resistant isolates of tuberculosis maybe caused by variety of reasons including patient characteristics (e.g. number of previous retreatments, treatment outcome, co-infection with different *M.*

tuberculosis strains), specimen (e.g. sputum volume and quality), and procedural factors (e.g. using the same sputum sample for both tests).[5-8]

The number of discrepancies are increasing nowadays, including between GeneXpert (MTB/RIF) and drug-susceptibility testing. An example of discrepancy is a GeneXpert (MTB/RIF) result indicated the *M. tuberculosis* isolate was rifampicin-sensitive, but the drug-susceptibility test showed rifampicin-resistance. Interpreting discrepant results in a patient suspected of tuberculosis has often confuse clinicians and laboratory personnel. This may partly cause the longer time to diagnose tuberculosis that leads to delay of treatment.[9,10]

This study was conducted to investigate the discrepancies between GeneXpert (MTB/RIF) and drug-susceptibility test in diagnosing tuberculosis drug resistance and which factors were associated with those discrepancies. The other purpose of this study was to measure the proportion of different types of drug-resistant tuberculosis cases in Indonesia, as well as identified the factors that affected the occurrence of multi-drug resistant tuberculosis in Indonesia.

Methods

This was a cross-sectional study involving all drug resistant pulmonary tuberculosis patients at Persahabatan General Hospital, Jakarta over a three-year period (January 2015 to December 2017). This study has been granted an ethical approval from the Ethical Committee of the Faculty of Medicine Universitas Indonesia. The data was obtained from eTB Manager for Indonesia version 2.0-b1022, a software program that records information about patients with drug-resistant tuberculosis. The inclusion criteria was if the patient had GeneXpert (MTB/RIF) and drug-susceptibility test results. We did descriptive analysis of patient characteristics (age, gender, number of previous treatments, HIV status, sputum sample, acid-fast stain, and tuberculosis severity). We also measured the proportion of resistance pattern, multi-drug resistant suspect criterion, and treatment outcomes.

Data of patient characteristics was further analyzed to identify the factors influencing: (1) the occurrence of any discrepancy between GeneXpert (MTB/RIF) and drug-susceptibility test result and (2) occurrence of multi-drug resistant tuberculosis. In addition, we analyzed the comparison of GeneXpert (MTB/RIF) and drug-susceptibility test in diagnosing drug resistant tuberculosis. Pearson chi-square test was used to determine significant associations or differences between groups. The obtained data was statistically analyzed by Statistical Package for the Social Science (SPSS) version 24.0 (IBM, Chicago, IL, USA). $P < 0.05$ was considered as statistically significant.

Result

Patient characteristics

Among 1 101 patients recorded in eTB manager of Persahabatan General Hospital in Jakarta, 683 patients that suffice the inclusion criteria were analyzed. Those patients had drug-resistant pulmonary tuberculosis that was confirmed positive by GeneXpert (MTB/RIF) and/or culture method (drug-susceptibility test).

Table 1 illustrate patient characteristics by ages, gender, and clinical parameter. The percentage of drug-resistant tuberculosis cases was 12% in those who aged 24 years or younger. This number was increasing until 25% in 45-54 age group. Drug-resistant tuberculosis cases were found in 17% of 55 years and over. Based on clinical characteristics, most patient had one history of previous treatment (44.7%), negative HIV (88.9%), same sputum sample (59%), positive acid-fast stain (69.4%), and not severe tuberculosis (78.6%).

Based on the drug-susceptibility test result, the resistance pattern was classified into five types of diagnoses. In this study, multi-drug resistant tuberculosis that resistant to both rifampicin and isoniazid was the most prevalent (35%). This was followed with the sum of people with pre-extremely drug-resistant (pre-XDR) tuberculosis (resistant to rifampicin, isoniazid, and a fluoroquinolone or a second-line injectable agent) which have similar proportion of 33%. Drug-resistant (drug-resistant) tuberculosis (resistant to either rifampicin or isoniazid) and extremely drug-resistant (XDR) tuberculosis (resistant to rifampicin, isoniazid, and a fluoroquinolone and a second-line injectable agent) were found in 15% and 13% of the patients. Only 4% of the patients who were drug-sensitive (sensitive to rifampicin but was detected as rifampicin-resistant by GeneXpert (MTB/RIF)).

Discrepancies of diagnosing drug-resistant tuberculosis

Most of the patients had positive result from GeneXpert (MTB/RIF) and drug-susceptibility test, however, discrepancy was found in the result of 48 patients. There are four possible outcomes of discrepancies: (1) rifampicin-resistant by GeneXpert (MTB/RIF), but rifampicin-sensitive by drug-susceptibility test, (2) rifampicin-sensitive by GeneXpert (MTB/RIF) but rifampicin-resistant by drug-susceptibility test, (3) *M. tuberculosis*-negative by GeneXpert (MTB/RIF) but rifampicin-resistant by drug-susceptibility test, (4) indeterminate by GeneXpert (MTB/RIF) but rifampicin-resistant by drug-susceptibility test. All of these types were treated as drug-resistant tuberculosis. The most common type of discrepancy was rifampicin-resistant by GeneXpert (MTB/RIF), but rifampicin-sensitive by drug-susceptibility test (36 cases) as showed in Figure 2.

This study analyzed the association of patient characteristics with GeneXpert (MTB/RIF) and drug-susceptibility test discrepancy. As suggested in Table 2, the proportion of age ranged between 12.5% in youngest group (≤ 24 years) to 25% in oldest group (≥ 55 years). The percentage of remaining age groups averaged around 20%. There were more female patients (62.5%) that had discrepant result. In terms of clinical aspect, the patients generally used different sputum samples (68.8%), had one history of retreatment (39.6%), negative HIV status (93.8%), positive acid-fast stain (66.7%), and not severe tuberculosis (87.5%). Based on Pearson chi-square test, there were two factors that statistically associated with the emergence of GeneXpert (MTB/RIF) and drug-susceptibility test discrepancy: increased number of retreatments ($p = 0.009$) and the use of the different sputum samples for Xpert and drug-susceptibility test ($p < 0.001$).

Factors influencing drug-resistant tuberculosis diagnosis

This study also analyzed the comparison of GeneXpert (MTB/RIF) and drug-susceptibility test in diagnosing drug

resistant tuberculosis as well as the association between patient characteristics and occurrence of multi-drug resistant tuberculosis. Multi-drug resistant tuberculosis is defined as a tuberculosis infection that is resistant to at least isoniazid and rifampicin. From the statistical analysis, there was no significant difference between the GeneXpert (MTB/RIF) and drug-susceptibility test to make the diagnosis of any drug resistant tuberculosis ($p = 0.051$). This study found the factor influencing the occurrence of multi-drug resistant tuberculosis diagnosis was re-treatment cases (Table 3).

DISCUSSION

GeneXpert (MTB/RIF) and conventional drug-susceptibility test as diagnostic tools for tuberculosis

Diagnosing tuberculosis can be difficult because of the abundance of tools available. The World Health Organization recommends that endemic countries screen tuberculosis-suspected patients with history taking, chest x-ray, and GeneXpert (MTB/RIF). These tools assist in commencing the appropriate treatment earlier. However, drug-susceptibility test is the gold standard for diagnosing tuberculosis and its drug resistant strains, so it is still required to confirm the diagnosis. Both the GeneXpert (MTB/RIF) and conventional drug-susceptibility test should be done in high-burdened, low-resource countries. In short, GeneXpert (MTB/RIF) serves as a screening tool while the drug-susceptibility test confirms the type of bacterial resistance.[1,11,12]

The GeneXpert (MTB/RIF) has high sensitivity and specificity for detecting pulmonary tuberculosis. Narute et al[12] described that the sensitivity and specificity of GeneXpert (MTB/RIF) was 96.9% and 87% respectively for pulmonary tuberculosis. However, GeneXpert (MTB/RIF) can detect both live and dead bacteria, thus is not suitable for treatment monitoring. GeneXpert (MTB/RIF) is useful for rapid (less than two hours) detection of tuberculosis and identification of rifampin resistance in countries with a high prevalence of tuberculosis such as India and Indonesia.[1,12]

There was relatively good concordance between molecular- and culture-based methods for rifampicin-resistant tuberculosis in our study (93%) compared to previous studies.[6,13,14] In other words, we found that 48 out of 683 cases or 7% had a discrepancy when conducting GeneXpert (MTB/RIF) and drug-susceptibility test. In comparison with other study, about 2% cases that underwent a genotypic and phenotypic test for multi-drug resistant tuberculosis diagnosis demonstrated inconsistency.[5] However, our study found there was no statistically significant difference between the diagnostic performance of GeneXpert (MTB/RIF) and conventional drug-susceptibility test method for detection of multi-drug resistant tuberculosis. This finding is similar to other study.[15]

Similar to other findings,[6,13] the discrepancy rates for rifampicin were higher with GeneXpert (MTB/RIF) than conventional drug-susceptibility test (figure 2). This may be due to false positives result of GeneXpert (MTB/RIF). The cause of false positives including the presence of dead bacterial in sputum and silent mutations. For instance, a silent mutation in the *rpoB* gene can be detected by the GeneXpert (MTB/RIF) as positive for rifampicin resistance. However other study found that GeneXpert (MTB/RIF) has a higher sensitivity and specificity relative to culture.[8] In order to truly define what cases were rifampicin-resistant, the drug-susceptibility test should be repeated and the sensitivity and specificity of GeneXpert (MTB/RIF) in Persahabatan General Hospital Jakarta can be determined. Without that data, this study suggests that GeneXpert (MTB/RIF) detected more rifampicin-resistant cases than drug-susceptibility test. In order to determine the mechanism of discrepancy, genome sequencing would deem useful. Nevertheless, utilizing GeneXpert (MTB/RIF) along with drug-susceptibility test can yield more accurate diagnoses, which supports World Health Organization recommendations.[1]

There are other possible reasons for the discrepancy to arise. These include a paucibacillary sputum sample, and high saliva or protein content in sputum sample. One likely reason for the discrepancy that was not assessed in this study was whether or not a patient had mixed infections with different *M. tuberculosis* strains.[5] Mixed *M. tuberculosis* co-infections may have given rise to mixed characteristics upon assessment. A well-known but controversial example is the Beijing family strains of *M. tuberculosis*, which are often associated with relapse due to drug resistance.[14,16] Because mixed *M. tuberculosis* infections may cause discrepancies, a solution to decrease these discrepancies would be to investigate whether or not heterogeneous genotypes were found in the isolates from each case of where a discrepancy occurred. As supported by other study, re-evaluation of the critical concentration of the drug used in culture-based drug-susceptibility test assays can confirm the resistance, especially if the infection is by a low-level rifampicin-resistance.[17]

Another theory is that the tuberculosis transmission has a new mechanism. This new phenomenon of tuberculosis transmission was seen when there was an endogenous reinfection caused by ongoing drug-resistant strain transmission. Some populations appear to have a low-level risk for this phenomenon, including Asians.[5]

Other causes of the discrepancies may be contamination, protocol procedures, nature of *rpoB* gene mutation, and viability of bacilli. For instance, the gene mutation may be silenced, thus accounting for the higher discrepancy frequency in GeneXpert (MTB/RIF) cases.[17] False positive GeneXpert (MTB/RIF) results due to a silent mutation in *rpo*B gene have been investigated in previous studies.[7, 18, 19] The basis explanation of this is associated with the method of GeneXpert (MTB/RIF) in using probes to detect the emergence of mutations of *rpo*B gene. The GeneXpert (MTB/RIF) assay show rifampicin resistant result due to failure of probe E to hybridize, indicating that *rpo*B gene mutation occurred in *M. tuberculosis* strain. However, the strain remains sensitive to rifampicin as shown by drug-susceptibility testing because the silent mutation has no effect on the rifampicin target.[7]

As for protocol and procedures, drug-susceptibility test requires technical proficiency to produce reliable and accurate. Even in the most competent laboratories, discrepant results can arise due to other reasons such as a failed first anti-tuberculosis treatment. Besides procedural skill, factors that influence laboratory results include bacterial population, different growth kineticism cross contamination, fastidious behavior of some strains, and minimum inhibitory concentration (MIC) of some isolates that were close to the critical concentration. Viability of bacilli could have been a factor, however the chest radiography was not available for the patients in this study. Evidence of a calcified Ghon complex,[20] which

typically does not contain viable bacilli, could influence the emergence of a genotypic-phenotypic discrepancy as well. The World Health Organization recommended the use of molecular-based tests such as MTBDRplus or GeneXpert (MTB/RIF) to give the diagnosis of multi-drug resistant tuberculosis in developing and high-burden countries, such as Indonesia. The MTBDRplus provides identification of rifampicin resistance by the detection of the most significant mutations of the *rpoB* gene (coding for the β-subunit of the RNA polymerase). It can also test for the isoniazid resistance; the *katG* gene (coding for the catalase peroxidase) is examined for highly level resistance and for testing the low level isoniazid resistance, the promoter region of the *inhA* gene (coding for the NADH enoyl ACP reductase) is analyzed. The GenoType MTBDRplus can be performed from pulmonary patient specimen or from culture isolates. The results are obtained within five hours, thus allowing early, appropriate treatment, which reduces transmission and spread of multi-drug resistant tuberculosis.[16] However, studies found that GeneXpert (MTB/RIF) demonstrated more accuracy in the detection of rifampicin-susceptibility for discrepant isolates compared with DRplus. Nevertheless, the overall concordance with Löwenstein–Jensen-based drug-susceptibility test was similar for both GeneXpert (MTB/RIF) and DRplus assay.[21]

Factors influencing GeneXpert (MTB/RIF) and drug-susceptibility test discrepancies

Our study suggested factors that significantly affected discrepancies are number of previous anti-tuberculosis treatments and using same sputum sample ($p < 0.05$). Anti-tuberculosis drug resistance is a manmade phenomenon that is driven by its treatment regimen. A small proportion of drug-resistant bacteria exist in all population of drug-susceptible *M. tuberculosis*. In the cases studied here, a failed first anti-tuberculosis treatment may have selected the drug-resistant *M. tuberculosis* bacteria. The expansion of such drug-resistant *M. tuberculosis* uses the same mechanisms as that with drug-susceptible tuberculosis.[5] If these cases carried a *M. tuberculosis* strain such as the Beijing type, resistance may have developed, especially during the first treatment. Furthermore, mechanisms of resistance are suggested to be region-specific. Gene sequencing to determine the mechanism of resistance and mapping would be useful to confirm their reasoning.

GeneXpert (MTB/RIF) and conventional drug-susceptibility test were conducted but the tests did not always use the same sputum sample. This issue gave rise to a significant relationship in the rise of a discrepancy. During the time between sputum collections, the tuberculosis infection may have manifested differently within the patient's body.

Usually *M. tuberculosis* grows with two processes: a slower initial growth and then a faster secondary growth that drives out the first process. However, multi-drug resistant and extremely drug resistant tuberculosis isolates appeared to have a delayed or missing secondary growth process, according to one study in California. This phenomenon is of grave concern because it allows the bacterium to escape growth-based phenotypic detection. The World Health Organization recommendation to use phenotypic detection methods remains the most prevalent method and is recommended for determining resistance. Hence, *M. tuberculosis* that are drug-resistant escape the phenotypic detection and resistant isolates would be labeled as "susceptible".[22] Because standard treatment regimen would continue, the drug-resistant *M. tuberculosis* be provided time for its expansion and perhaps additional resistance.

There are specific procedures that should be sought or corrected in order to decrease the discrepancies. Same sputum should be used when conducting the GeneXpert (MTB/RIF) and drug-susceptibility testing. Additionally, that sample should be collected in the morning and proper care should be taken to obtain a good quality sample, i.e. more purulent and less saliva. There should also be a functional quality control assurance program preferably ran by the central or most sophisticated laboratory. Most importantly, there should be a good communication between the physician and lab clinicians when a discrepancy arises, so they can discuss it immediately and analyze why it occurred. The emergence of a discrepancy leads to possible mistreatment and perhaps further development of drug resistant tuberculosis infections.

A better understanding of the discrepancies' local causal pathways could assist better-targeted public health responses. Simply "turning off the tap" through improved programmatic management of drug-susceptible tuberculosis will be insufficient to contain the spread of drug-resistant tuberculosis.[23]

Factors influencing drug resistant tuberculosis cases

Our study suggested that the patient's treatment history influenced the occurrence of multi-drug resistant tuberculosis diagnosis. Most of the drug-resistant diagnosis had some number of previous treatments (Table 1) and there was a significant relationship between re-treatment cases and multi-drug resistant tuberculosis ($p < 0.05$). The higher proportion of multi-drug resistant tuberculosis among re-treatment cases may be explained by the difficulty of diagnosing multi-drug resistant tuberculosis at first presentation. As for re-treatment multi-drug resistant tuberculosis cases in Indonesia, it is likely that the resistance is due to initial drug-susceptible tuberculosis with resistance amplification during primary treatment. This indicates that improved treatment adherence should be a major public health priority. One public health program is Directly Observed Treatment, Short Course (DOTS), which has demonstrated ability to improve treatment outcomes. DOTS has been implicated in order to reduce the burden of tuberculosis. Implementation of such programs requires strong political commitment along with substantial and sustainable financing, especially in low- or middle-income countries.[23]

The pathogenesis of drug-resistant tuberculosis can be driven by numerous factors. The traditional factors driving drug resistance are poor compliance and programmatic failure. More novel explanations describe that the resistance is driven by pharmacokinetic variability, induction of efflux pumps that transport the drug out of cells, and suboptimal drug penetration into tuberculosis lesions. These factors are crucial to the pathogenesis of drug-resistant tuberculosis.[24]

Limitations of the study

Some issues may have created an overestimate of multi-drug resistant tuberculosis in this study. The inability to study a more random population is the major limitation of the study. For instance, it was possible that the hospital where the data was obtained attracts particular patients

who have a poor compliance to anti-tuberculosis regimen or have co-infections with tuberculosis. Using data from different geographical regions would yield more generalized results. In addition, some multi-drug resistant tuberculosis cases were referred cases without complete medical history. The exclusion criteria may had eliminated patients who were linked to a pattern of discrepancy, which this study did not discover. Patients who could not have both GeneXpert (MTB/RIF) and drug-susceptibility test may influence the demographics and clinical aspects of the studied population.

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Tables

Patient characteristics		Drug-resistant tuberculosis cases (N)	%
Age (years)	≤24	83	12.2
	25-34	149	21.8
	35-44	164	24.0
	45-54	171	25.0
	≥55	116	17.0
Gender	Female	263	38.5
	Male	420	61.5
Number of previous treatments	0	42	6.1
	1	305	44.7
	2	260	38.1
	3	59	8.6
	4	11	1.6
	5	5	0.7
	6	1	0.1
HIV status*	Positive	13	1.9
	Negative	607	88.9
Sputum sample	Same	403	59.0
	Different	280	41.0
Acid-fast stain*	Positive	474	69.4
	Negative	162	23.7
Tuberculosis severity*	Severe	99	14.5
	Not Severe	537	78.6
Resistance pattern	Drug-sensitive†	26	3.8
	drug-resistant	105	15.4
	MDR	239	35.0
	Pre-XDR	227	33.2
	XDR	86	12.6
MDR suspect criterion	New	26	3.8
	Relapse	257	37.6
	Negligent	129	18.9
	Failure on initial treatment	135	19.8
	Failure on retreatment	103	15.1
	Others	33	4.8
Treatment outcome*	Cured	94	13.8

	Completed	2	0.3
	Defaulted	150	22.0
	Failed	40	5.9
	Died	63	9.2

Table 1. Descriptive Characteristics of Drug-resistant Tuberculosis Cases

Note: *Variables and number of missing data: HIV 64 cases, acid-fast stain 47 cases, tuberculosis severity 47 cases, treatment outcome 428 cases. †Drug-sensitivity that was detected by GeneXpert (MTB/RIF)
Abbreviation: HIV: human immunodeficiency virus; Rif: rifampicin; drug-resistant: drug-resistant; MDR: multidrug-resistant; Pre-XDR: pre-extremely drug-resistant; XDR: extremely drug-resistant.

Patient characteristics		Discrepant result (N=48)	%	P-value
Age (years)	≤24	6	12.5	
	25-34	9	18.8	
	35-44	11	22.9	0.571
	45-54	10	20.8	
	≥55	12	25.0	
Gender	Female	30	62.5	0.882
	Male	18	37.5	
Number of previous treatments	0	6	12.5	
	1	19	39.6	
	2	14	29.2	
	3	7	14.6	0.009†
	4	1	2.1	
	5	1	2.1	
	6	0	0.0	
HIV status*	Positive	2	4.2	0.112
	Negative	45	93.8	
Sputum sample	Same	15	31.3	<0.001†
	Different	33	68.8	
Acid-fast stain*	Positive	32	66.7	0.221
	Negative	15	31.3	
Tuberculosis severity*	Severe	5	10.4	0.242
	Not Severe	42	87.5	

Table 2. Factors Influencing GeneXpert (MTB/RIF) and Drug-Susceptibility Test Discrepancy

Note: *Variables and number of missing data: HIV 1 cases, acid-fast stain 1 case, tuberculosis severity 1 case. †$p < 0.05$, chi-square test
Abbreviation: HIV: human immunodeficiency virus

Patient characteristics	P-value
Age (years)	0.413
Gender	0.198
Re-treatment case	0.045*
HIV status	0.410

Sputum sample	0.515
Acid-fast stain	0.393
tuberculosis severity	0.901

Table 3. Factors Influencing the Occurrence of Multi-Drug Resistant Tuberculosis
Note: *p < 0.05, chi-square test
Abbreviation: HIV: human immunodeficiency virus

Figure

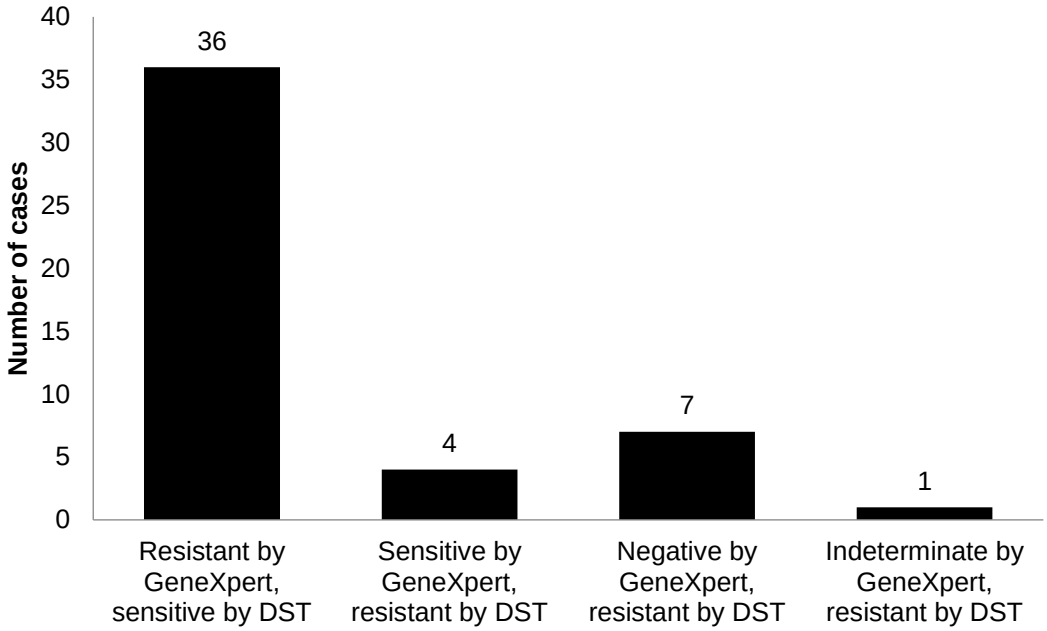

Figure 1. Types of discrepancy.
Note: There were four types of discrepancies discovered between GeneXpert and drug-susceptibility testing.
Abbreviation: DST: drug susceptibility-test