Extensively drug-resistant tuberculosis as a cause of death in patients co-infected with tuberculosis and HIV in a rural area of South Africa

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Summary

Background The epidemics of HIV-1 and tuberculosis in South Africa are closely related. High mortality rates in co-infected patients have improved with antiretroviral therapy, but drug-resistant tuberculosis has emerged as a major cause of death. We assessed the prevalence and consequences of multidrug-resistant (MDR) and extensively drug-resistant (XDR) tuberculosis in a rural area in KwaZulu Natal, South Africa.

Methods We undertook enhanced surveillance for drug-resistant tuberculosis with sputum culture and drug susceptibility testing in patients with known or suspected tuberculosis. Genotyping was done for isolates resistant to first-line and second-line drugs.

Results From January, 2005, to March, 2006, sputum was obtained from 1539 patients. We detected MDR tuberculosis in 221 patients, of whom 53 had XDR tuberculosis. Prevalence among 475 patients with culture-confirmed tuberculosis was 39% (185 patients) for MDR and 6% (30) for XDR tuberculosis. Only 55% (26 of 47) of patients with XDR tuberculosis had never been previously treated for tuberculosis; 67% (28 of 42) had a recent hospital admission. All 44 patients with XDR tuberculosis who were tested for HIV were co-infected. 52 of 53 patients with XDR tuberculosis died, with median survival of 16 days from time of diagnosis (IQR 6–37) among the 42 patients with confirmed dates of death. Genotyping of isolates showed that 39 of 46 (85%, 95% CI 74–95) patients with XDR tuberculosis had similar strains.

Conclusions MDR tuberculosis is more prevalent than previously realised in this setting, XDR tuberculosis has been transmitted to HIV co-infected patients and is associated with high mortality. These observations warrant urgent intervention and threaten the success of treatment programmes for tuberculosis and HIV.

Introduction

Tuberculosis is the most common cause of morbidity and mortality in individuals with HIV-1 infection in sub-Saharan Africa.1 HIV greatly increases the risk of active tuberculosis disease2 and about 80% of patients presenting with active tuberculosis in the province of KwaZulu Natal, South Africa, are co-infected with HIV. Mortality rates of up to 40% per year have been reported in patients co-infected with tuberculosis and HIV who are receiving treatment for tuberculosis, but not for HIV.3 Although antiretroviral therapy is likely to reduce HIV-associated morbidity and mortality as it becomes more widely available, any reduction is likely to be blunted if efforts are not taken to improve tuberculosis programmes concurrently.4,5

The number of tuberculosis cases in sub-Saharan Africa has increased substantially in the past decade, fuelled by the HIV epidemic,6 making it difficult for tuberculosis programmes to improve outcomes.5 In South Africa, the national DOTS treatment success rate has been reported to be only 67%,7 well below the WHO standard of 85%.8 Low rates of treatment completion place patients at risk for relapse of tuberculosis disease as well as for development of drug-resistance.
tuberculosis, defined as resistance to at least isoniazid, rifampicin, fluoroquinolones, and either aminoglycosides (amikacin, kanamycin) or capreomycin, or both. This finding raised the concern that not only MDR tuberculosis, but also XDR tuberculosis, was emerging in this region with high HIV prevalence. We therefore undertook a study to assess the extent of MDR tuberculosis and XDR tuberculosis in this rural area in South Africa. We also aimed to describe characteristics and treatment histories of individuals with XDR tuberculosis in this setting.

Methods
Setting and study population
We did this study in the Msinga sub-district of KwaZulu Natal, South Africa, a 2000 km² rural area, which is home to 300,000 traditional Zulu people. A provincial government district hospital of 355 beds is the focus of health care for this population. 40% of inpatient beds in this hospital are occupied by patients infected with HIV, and the prevalence of HIV infection in women presenting to the maternity ward is 20%. A government-sponsored tuberculosis treatment programme, using the WHO DOTS strategy, has been in place in this district since 1993. Patients receive free treatment for tuberculosis by home-based directly observed therapy, administered by volunteer community health workers. The standard regimen, regardless of HIV status, is isoniazid, rifampicin, ethambutol, and pyrazinamide for 2 months, followed by 4 months of isoniazid and rifampicin. Diagnosis is typically made by sputum microscopy for acid-fast bacilli, x-ray, or clinical criteria, according to the South African National Tuberculosis Guidelines. Sputum cultures are not routinely done in patients suspected of having tuberculosis for the first time, but are done in those with treatment failure or recurrence. Patients identified as having MDR tuberculosis are referred to a dedicated tuberculosis hospital in metropolitan Durban, where most second-line drugs are available (at the time of the study, capreomycin and para-aminosalicylic acid were not available in South Africa).

A government-sponsored antiretroviral therapy programme was started at this study site in March, 2004. Patients with CD4-positive T-lymphocyte (CD4) counts of less than 200 cells per mm³ were eligible for free antiretroviral treatment. By September, 2006, nearly 1300 patients had been enrolled from this site.

Patients were included in this study from January, 2005, to March, 2006, and divided into three groups. Group 1 included consecutive patients in whom a tuberculosis culture was done in accord with the South African guidelines between January and May, 2005. This group consisted of individuals with persistently smear-positive sputum specimens and those with recurrent tuberculosis. Group 2 included all inpatients present on the male and female tuberculosis wards on a single day in February, 2005. Group 3 consisted of consecutive inpatients and outpatient patients who presented with signs and symptoms of tuberculosis (eg, cough, fever, weight loss) at the district hospital between June, 2005, and March, 2006.

Procedures
Sputum samples were obtained from all patients for mycobacterial culture and drug susceptibility testing. Typically, one to three samples were taken per patient. The samples were not induced and were taken at any time of day. Sputum specimens were stored at 4°C for up to 3 days until transport to the provincial diagnostic mycobacteriology laboratory in Durban. Digestion and decontamination was done with the N-acetyl-L-cysteine-sodium hydroxide method. An auramine-stained smear was made and the remaining deposit was inoculated in one mycobacteria growth indicator tube (MGIT) broth and on one Middlebrook 7H10 agar plate. The broths were incubated at 37°C in an automated incubator. Agar plates were sealed in CO₂-permeable plastic bags and incubated in 5% CO₂ at 37°C. Acid-fast microscopy was done on each positive MGIT broth when a positive reading was obtained. Those containing acid-fast bacilli were subcultured on Middlebrook 7H10 agar. Primary Middlebrook agar plates were read weekly for 3 weeks or until growth was observed. Microscopy was done to confirm the presence of acid-fast bacilli. All positive cultures were identified as Mycobacterium tuberculosis by means of niacin and nitrate reductase tests.

The risk of cross-contamination was minimised by processing samples individually in real time, rather than batching. Quality assurance was done weekly by the UK National External Quality Assessment Service programme, where ten consecutive isolates were fingerprinted to rule out cross-contamination.

Susceptibility tests were done on all isolates using the 1% proportional method on Middlebrook 7H10 agar. All isolates were tested for susceptibility to isoniazid (1 mg/L), rifampicin (2 mg/L), ethambutol (5 mg/L), streptomycin (2 mg/L), kanamycin (16 mg/L) and ciprofloxacin (2 mg/L). Susceptibility testing to pyrazinamide and the remaining four classes of second line drugs—ethionamide, cycloserine, capreomycin, and para-aminosalicylic acid—are not routinely done.

Genotyping by IS6110 fingerprinting and spoligotyping was done on isolates found to have resistance to first-line and second-line drugs. IS6110 fingerprints were analysed by GelCompar 4.0 software (Applied Maths, Kortrijk, Belgium); spoligotyping patterns were analysed by visual inspection. Strains were classified as belonging to the KwaZulu Natal (KZN) family of tuberculosis strains if there was a difference of two bands or less by IS6110 fingerprinting, or if fewer than five spacers were absent compared with the typical KZN pattern by spoligotyping.

Definitions, analysis, and outcomes
Positive cultures for Mycobacterium tuberculosis were categorised on the basis of drug susceptibility results, as: fully susceptible or resistant to one or more tuberculosis drugs, but not...
both isoniazid and rifampicin (non-MDR tuberculosis); resistant to at least both isoniazid and rifampicin (MDR tuberculosis); or resistant to at least isoniazid, rifampicin, fluoroquinolones, and either aminoglycosides (amikacin, kanamycin) or capreomycin, or both (XDR tuberculosis). We calculated prevalence rates of MDR and XDR tuberculosis among confirmed tuberculosis cases (patients with positive tuberculosis cultures) in group 3. The probability of having MDR or XDR tuberculosis in patients presenting to this district hospital with signs or symptoms of tuberculosis was also calculated in group 3.

We reviewed hospital medical records for all cases of XDR tuberculosis to determine patients’ demographics, previous tuberculosis treatment, previous hospital admission, HIV history, and vital status. Tuberculosis treatment history was classified by standard definitions: cure, treatment completion, treatment failure, default, transferred out, or death.21 For patients tested for HIV, information about most recent CD4 count and viral load was obtained, as well as any information about antiretroviral therapy.

The primary outcomes of interest were number of cases and prevalence rates of MDR and XDR tuberculosis. Secondary outcomes for patients with XDR tuberculosis were mortality, proportion with previous treatment for tuberculosis, proportion with previous hospital admission, HIV co-infection, and genotype of isolates. Differences in the duration of survival on the basis of patient’s characteristics and previous treatment were analysed with ANOVA.

The study was approved by the Ethics and Human Investigation Committees of the University of KwaZulu Natal and Yale University.

Role of the funding source
The sponsors of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results
We sent 2203 sputum specimens from 1539 individual patients for mycobacterial culture between Jan 1, 2005, and March 31, 2006. 542 patients had at least one culture that was positive for M tuberculosis. Table 1 shows the distribution of these patients and the classification of resistance over the three groups. In total, 221 cases of MDR tuberculosis were identified. Of these, 53 patients had XDR tuberculosis, with resistance to isoniazid, rifampicin, ethambutol, streptomycin, aminoglycosides, and fluoroquinolones.

Of the 1428 patients presenting to this district hospital with signs and symptoms of tuberculosis (group 3), 475 (33%) had active culture-positive tuberculosis (table 1). Among these confirmed cases, the prevalence of MDR tuberculosis was 39% (185) and of XDR tuberculosis was 6% (30). Among all patients presenting with signs and symptoms of tuberculosis, the probability of having MDR tuberculosis was 13% (185 of 1428) and XDR tuberculosis was 2% (30 of 1428).

Of the 53 patients with XDR tuberculosis, 25 (49%) were women and the median age was 35 years (range 20–75 years; table 2). Data on tuberculosis characteristics, previous treatment for tuberculosis, history of hospital admission, and HIV characteristics are presented in table 2. Notably, the majority of patients (55%) had never previously received treatment for tuberculosis, while an additional 30% had documented cure or completion of their previous tuberculosis treatment course. 67% of patients had been admitted to this district hospital for any cause in the 2 years preceding their presentation with XDR tuberculosis. Two patients with XDR tuberculosis were health-care workers in the hospital; both died of XDR tuberculosis. Four other hospital workers had been suspected of having the condition, but sought care at another hospital and as a result were not included in this cohort.

Contact tracing was completed for all 53 patients with XDR tuberculosis. They were from a dispersed geographical region with no known contact with each other apart from receiving health care from the same district hospital. None of the patients had a family member who was sick with tuberculosis before his or her illness.
All 44 patients with XDR tuberculosis who had been tested for HIV were infected with the virus (table 2). Their median CD4 count at the time of sputum collection was 63 cells per mm$^3$ (range 9–283). Viral loads on antiretroviral treatment were not available for any of these patients.

52 of the 53 (98%) patients with XDR tuberculosis died. Median survival from the time of specimen collection to death was 16 days (range 2–210 days, IQR 6–37) in the 42 patients with confirmed dates of death (the remainder died at home or outside of the community and their precise dates of death were not documented in the medical records). The figure shows that roughly 70% of patients died within 30 days from the time when their sputum was collected for culture. The duration of survival did not vary significantly on the basis of age, sex, data collection group, previous treatment for tuberculosis, previous hospital admission, HIV status, CD4 count, or use of antiretroviral drugs.

Genotyping has been completed for isolates from 46 patients with XDR tuberculosis to date. IS6110 fingerprinting was done on 16 of 23 patients in groups 1 and 2, and spoligotyping on all 30 patients in group 3. Genotyping showed that 39 of the 46 (85%; 95% CI 74–95) isolates tested were genetically similar, belonging to the KZN family of strains; 13 of 16 (81%) isolates in groups 1 and 2 and 26 of 30 (87%) in group 3.

**Discussion**

We undertook enhanced surveillance for drug-resistant tuberculosis by instituting routine mycobacterial culture and drug susceptibility testing on patients with suspected or diagnosed tuberculosis in a rural resource-limited setting, with a high prevalence of HIV, in South Africa. We found a substantially higher prevalence of XDR tuberculosis and MDR tuberculosis than previously reported. All patients with XDR tuberculosis who had previously been tested for HIV were co-infected with the virus. XDR tuberculosis disease in this population was rapidly, and almost uniformly, fatal.

The findings of our study cause concern for several reasons, beyond the lethal nature of the disease. More than half the patients with XDR tuberculosis had never been previously treated for tuberculosis; an additional third had either been cured or had completed treatment for previous tuberculosis illness. With only 15% of patients having treatment failure or default, most patients were unlikely to have developed resistant tuberculosis as a consequence of unsuccessful treatment. Instead, transmission of XDR strains between individuals has probably occurred; this assumption is supported by the genotyping results. About 85% of the XDR isolates were from the KZN family of tuberculosis strains, which was first described in 1996. At that time, the KZN strains were either fully susceptible or had resistance to only first-line tuberculosis drugs. Resistance to second-line drugs was not seen until the past 2–3 years, further supporting the notion of recent transmission of XDR tuberculosis to our patients.

It is also probable that transmission of the XDR tuberculosis strain occurred nosocomially. We found that two-thirds of patients were recently hospitalised before the onset of XDR tuberculosis and that two health-care workers, and possibly four others, died from XDR tuberculosis. These findings are reminiscent of MDR tuberculosis outbreaks worldwide in the past 20 years, in which drug-resistant strains transmitted nosocomially were responsible for extensive mortality in HIV patients. These findings are particularly worrying for resource-limited settings similar to the site of this study, where roughly 40% of patients admitted to hospital are HIV-infected and effective infection control facilities and practices are extremely limited.

"Tuberculosis is the most common opportunistic infection and cause of death among HIV-infected patients in resource-limited settings." Patients with HIV infections are particularly vulnerable to primary disease following infection with tuberculosis, and therefore are at high risk of illness and mortality when exposed to drug-resistant tuberculosis strains. Although antiretroviral therapy has reduced the incidence of active tuberculosis, HIV-infected patients on therapy still have a more than five-fold increased risk of developing tuberculosis compared with individuals without HIV infection. Although the combination of tuberculosis treatment and antiretroviral therapy can improve mortality in co-infected patients, it is less likely to do so in patients with drug-resistant tuberculosis. Compared with first-line treatment, second-line treatment for MDR tuberculosis requires a longer course, is more toxic, more costly, and is not readily available in resource-
limited settings. Treatment success in XDR tuberculosis is very difficult as few active drugs remain. Thus, drug-resistant tuberculosis and its nosocomial transmission threaten the achievements of DOTS and antiretroviral scale-up programmes, which are now widely being implemented in resource-limited settings worldwide.

A rapid and comprehensive approach is essential to tackle this ominous situation. First, the full extent of MDR and XDR tuberculosis in areas of high HIV prevalence needs to be ascertained. Resources are needed to establish laboratory capacity capable of undertaking mycobacterial culture and drug susceptibility testing to facilitate timely diagnosis and to assess prevalence of drug resistance, in resource-limited settings.

Second, tuberculosis treatment programmes must be strengthened to improve treatment completion rates and provide treatment for drug-resistant disease. Treatment completion rates in many resource-limited settings are well below the WHO standard of 85%. These low rates promote the development of drug-resistant strains, which could then result in their transmission. Treatment programmes providing second-line therapy for drug-resistant tuberculosis are needed to save lives and to reduce the further spread of drug-resistant strains.

Infection control facilities and practices are generally inadequate in most resource-limited settings. This shortcoming has undoubtedly contributed to magnitude of the problem in the present study. Improvements in infection control facilities and practices are crucial to break the cycle of transmission of drug-resistant tuberculosis, in addition to protecting health-care workers, an increasingly scarce resource in Africa and other resource-limited settings.

Last, simpler diagnostic tools for detecting active tuberculosis and drug resistance must be developed for dissemination in resource-limited settings. The current diagnosis of drug-resistant tuberculosis relies on mycobacterial culture and drug susceptibility testing, which are time consuming, labour intensive, and costly, when available. Accelerated development of new drugs is also essential. With currently available drugs, patients with XDR tuberculosis are left with few, if any, treatment options.

We recognise some limitations to our study. First, the investigation was done at a single site in rural South Africa. Although the full extent of MDR and XDR tuberculosis in South Africa and beyond is not known, growing evidence suggests that cases are not confined to a local cluster. The presence of MDR and XDR tuberculosis has been documented in 28 other hospitals in KwaZulu Natal, all provinces in South Africa and worldwide. Second, our data are limited by the unavailability of drug susceptibility testing for all classes of second-line drugs in South Africa. The isolates in our study were resistant to all first-line drugs for which tests were done and the two most important classes of second-line drugs: aminoglycosides and fluoroquinolones. Although susceptibility results from the remaining classes were not available, the rapid and near-complete mortality in this population shows the potential grave consequences of transmission of drug-resistant tuberculosis strains in high HIV prevalence setting.

Third, duration of survival was calculated from time of sputum collection rather than from the time of initial tuberculosis diagnosis or time of treatment initiation, because the sputum culture represents the first confirmation of XDR tuberculosis infection. Culture data from earlier points in their illness were not available for all patients in groups 1 and 2, since routine culture at the time of initiation of anti-tuberculosis therapy is not recommended by South Africa tuberculosis control guidelines. Therefore, we were unable to ascertain whether patients were ill from XDR tuberculosis from the time of their initial diagnosis or treatment initiation, or whether they were later reinfected or superinfected with an XDR tuberculosis strain. Lastly, our data provide characterisation of patients with XDR tuberculosis only. Similar data for patients with MDR and drug-susceptible tuberculosis are necessary to help identify predictive factors for resistant disease.

Despite these limitations, this study provides disturbing new evidence of the presence and serious consequences of drug-resistant tuberculosis in a resource-limited area, with a high prevalence of HIV, and highlights the need for urgent local and international intervention.

Contributors
All authors contributed to the conception and design of the study, analysis and interpretation of data, and to drafting or critical revision of the article. Data were acquired by A Moll, A W Sturm, R Pawinski, J Andrews, and G Friedland.

Conflict of interest statement
We declare that we have no conflict of interest.

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