The resurgence of tuberculosis in Russia

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This paper documents and attempts to explain the epidemic spread of tuberculosis (TB) in Russia during the 1990s. After several decades of decline, the notification rate of all new TB cases among permanent residents increased by 7.5% per year from 1991–1999 and the death rate by 11% per year. Growth was quickest from 1993–1995 but increased again after the economic crisis of August 1998. Approximately 120 000 new cases and 30 000 deaths were reported in 1999. Case detection and cure rates have fallen in Russia since the mid-1980s; the fall has been accompanied by a higher frequency of severe disease among cases, and higher death and case fatality rates. With a mathematical model describing the deterioration in case finding and cure rates we could replicate the average rate of increase in incidence 1991–1999 but not the precise timing of the observed changes. Other factors that probably helped to shape the observed rise in caseload include enhanced transmission due to the mixing of prison and civilian populations, an increase in susceptibility to disease, and changes in the proportion of cases detected by surveillance. Although our explanation for the resurgence of TB is incomplete, we have identified a set of measures that can be implemented now to cut transmission, incidence and deaths.

Keywords: tuberculosis; outbreak; Russia; surveillance; drug resistance; transmission

1. INTRODUCTION

Russia reported over 120 000 new cases of tuberculosis (TB) and nearly 30 000 deaths in 1999, at the end of a decade of explosive growth in TB. The resurgence of TB has been seen throughout Eastern Europe, but the increase reported by Russia has been much steeper than average (WHO 2000a).

There are, broadly, two possible reasons why TB has made such a dramatic comeback. The first, direct cause, is the deterioration of TB control services: a sharp reduction in funds for TB control has led to drug shortages (most acutely in 1998) and a less effective system of patient diagnosis and management. This meant that, from the mid-1980s onwards, a smaller fraction of patients was treated, delays to diagnosis became longer, and cure rates were lower. We can reasonably infer that poor case management has led to more deaths, more transmission, and hence more new cases.

The second possibility is that transmission and susceptibility to TB have increased because social and economic conditions have had a broader, negative impact on Russian health. High labour turnover and unemployment (Fedorov 1999), declining social cohesion and equality (Walberg *et al.* 1998), stress (Stone 2000) and war at Russia's geographical margins have been thoroughly documented. A dramatic fall in life expectancy since 1984 has been associated to the rise of alcoholism, circulatory diseases, accidents and violence (Leon *et al.* 1997). Studies done outside Russia have linked a quicker progression from mycobacterial infection to disease with malnutrition (Palmer *et al.* 1957), and possibly alcohol abuse (Rieder 1999) and stress (Comstock 2000). Inside Russia, in civil

society and in crowded prisons (Stern 1999; Farmer *et al.* 1999), these and other risk factors exist in abundance, potentially generating more TB as part of the mounting burden of respiratory disease (Leon *et al.* 1997).

It is obvious that the re-growth of TB cases and deaths presents a serious problem for Russia. However, a large fraction of the rich body of data describing this outbreak remains unavailable outside the country (Shilova 1999). It seems likely that the new outbreak has been driven both by increased transmission and by a growing susceptibility to disease, but no attempt has yet been made to quantify the relative contribution of these different processes.

In this paper, we begin by documenting the growth of TB in Russia during the past decade, more fully than has been done in previous publications (Farmer *et al.* 1999; Perelman 2000). We then attempt to investigate whether the rise in TB cases was due specifically to the failure of TB control services, as distinct from the general deterioration in social and economic conditions. This understanding is needed in order to forecast the trajectory of the TB epidemic, and for assessing the potential impact of planned improvements in TB control nationwide. Close scrutiny of the surveillance and laboratory data also reveals various limitations of TB diagnosis and treatment in Russia now; we identify the main weaknesses, and propose some topics for economic and epidemiological research that could lead to a more efficient allocation of resources.

2. TUBERCULOSIS SURVEILLANCE IN RUSSIA

Russia's 79 provinces (*oblasts*), unified in 11 territories, submit aggregated data on the diagnosis and management of TB cases annually to the Ministry of Health. Case

Figure 1. Trends in case notifications 1970–1999 and projections to 2005. Series represent all reported TB cases (filled circles), all cases among permanent residents (open circles), cases in children 0–14 years (squares), and extrapulmonary cases (triangles). Solid lines are projections made (a) by fitting a mathematical model to data for permanent residents, (b) by extrapolation of case reports for 1996–1999. The logarithmic scale distinguishes the different rates of growth and decline for adults, children and extrapulmonary cases.

reports are collated on two forms. Form 8 contains data on the number of new TB cases (i.e. those not previously treated), classified by age and sex, as respiratory (lungs, pleura, upper respiratory tract and bronchi, intrathoracic lymph nodes) or non-respiratory disease, and whether bacteriologically confirmed (sputum and other material examined by smear microscopy or culture). Since the early 1990s, the intention has been to record on form 8 data on all new TB patients in Russia, including those treated outside Ministry of Health institutions. These other cases are among the homeless, prisoners, armed forces, immigrants and non-residents. In 1995, 30 out of 89 *oblasts* complied; by 1998, this number had increased to 79. Form 8 is a steadily improving tool for reporting on all new TB cases in the Russian Federation.

Form 33 includes patients treated in Ministry of Health institutions only, often termed 'permanent residents'. It follows them throughout their course of treatment in a series of dispensary groups, thereby providing data on both incidence and prevalence. A full account of the dispensary groups is beyond the scope of this paper. Here we need only refer to groups I, II and V, which contain patients considered to have active disease. Group I includes cases under treatment that have been confirmed by bacteriological examination, or diagnosed by chest X-ray with clinical signs. Patients move to group II after completing treatment and showing two negative cultures; they remain under observation in that group for a further six months. Group V contains patients with active (VA) or abating (VB) extrapulmonary TB, including meningeal and ocular disease. All *oblasts* currently report on form 33 each year.

As well as classifying cases by age, sex and type of TB, form 33 records treatment outcomes, surgical procedures, deaths, transfers between treatment centres, and the number of patients in hospitals, including sanatoria. The

Figure 2. Variable growth rate of the outbreak of TB from 1991–1999, measured by annual changes in notification rates for all cases (filled circles), and for cases in permanent residents (open circles). Crosses represent annual changes in the incidence rate obtained from the mathematical model; the maximum-likelihood fit fails to replicate the observed growth in number of cases.

principal treatment outcomes are (a) bacteriological conversion, from positive to negative, judged by (mainly) sputum culture or smear microscopy; (b) closure of lung cavities, ascertained by chest X-ray. Treatment success is measured by the proportion of patients registered in one year that have a positive outcome by the end of the following year, i.e. after an average of 18 months. This measure does not necessarily reflect the ultimate outcome of treatment, but is useful for following trends. The case fatality rate is the proportion of patients dying within 12 months on average, and does not include registered patients who die later of TB. Form 33 also reports cases detected by X-ray screening, infected contacts (ascertained by tuberculin skin test) of active cases, contacts placed on preventive treatment and active cases arising among contacts. One measure of case finding effort used in this paper is the number of individuals given a chest X-ray or tuberculin skin test divided by the total population size. This is an imperfect index because it reflects active case finding only, when in reality cases are detected actively and passively.

In the next section, we present data collected on form 8 for the period 1970–1999, and on form 33 for the period 1991–1999.

3. RESULTS

(a) Case notifications

In 1999, a total of 124 044 new cases were reported (form 8, all forms of TB, data from all ministries), 13 109 more than in 1998. The notification rate in 1999 was 85.2 per 10^5 population, and has increased by 11.5% per year on average since 1991 (figure 1). Growth was faster than average between 1993 and 1996 due to a real increase in incidence (1993 peak in figure 2) and to improved reporting (1995 peak). The number of TB patients found with mycobacteria in sputum and other material (by culture or smear) was 44 838 in 1999 or 30.8 per 10^5 population, and the rate has been growing at an average of 9.4% per year since 1991.

Figure 3. Distribution of the case notification rate by age in 1999 (data from form 8).

The number of cases reported among permanent residents (form 33) was 87 258 in 1999, or 60.0 per 10^5 , and growing at an average of 7.5% per year since 1991 (doubling in 9 years; figures 1 and 2). The number of cases detected by Ministry of Health (MOH) surveillance has grown more slowly than the total number, in part because form 8 has captured, since 1995, an increasing fraction of cases from prisons and among the homeless, immigrants and foreigners.

The highest incidence of TB in 1999 was in persons aged 25–34 years (154 per 10^5), both for males (198 per 10^5) and females (70.5 per 10^5 , figure 3), including the large population of relatively young adults in prisons (form 8). The overall incidence of tuberculosis in males was 3.7 times higher than in females (139.0 and 37.8 per 10^5 , respectively).

Reports of extrapulmonary TB cases (group V) show a different pattern. The case notification rate has increased by only 1.8% per year since 1991, rising to 5335 new cases in 1999 (figure 1). And the rate in females (3.8 per 10^5) was about the same as in males (3.5 per 10^5).

Because children develop TB from more recent infections on average, the incidence of childhood (0–14 years) disease was falling more quickly (6.1% per year) than incidence in the whole population (3.7% per year) over the period 1970–1991 (figure 1). Since then, it has increased at about the same rate (9.0% per year). Among children 4938 new cases were reported in 1999, with approximately the same case rates among boys (17.3 per 10^5) and girls (18.5 per 10^5). As usual, relatively small fractions of children (0–14 years, 304, 6.2%) and teenagers (15–17 years, 673, 26.2%) had bacteriologically positive sputum (13.0% in all new cases).

The incidence of TB among contacts of all active cases has been increasing at an average of 10.1% per year since 1991, reaching an extraordinarily high rate of 801 per 10^5 in 1999 (891 per 10^5 in contacts of sputum-positive cases). Personnel of the TB services were also at high risk of contracting the disease: 348 out of 70 468 (494 per 10^5) staff developed TB in 1999, about six times the rate in the population at large.

Figure 4. Changes in treatment success 1972–1999, measured by bacteriological conversion (filled circles) and the closure of lung cavities (open circles). The unmarked line is the relative failure rate calculated from $(100 - \text{per cent conversion})/100$, and scaled to the 1982 value.

In 1999, 40 462 respiratory TB cases (53.2% of all new cases) were detected by X-ray screening. As is usual with active case finding, mycobacteria were cultured from a relatively small fraction of these cases (4827, 11.9%), and still fewer had positive sputum smears (2490, 6.1%).

(b) Outcomes of treatment

The proportion of patients cured has been falling throughout the 1990s (figure 4). Among patients with lung cavities registered in 1998, only 61.8% had closed cavities by the end of 1999. Among patients with mycobacteria cultured from sputum in 1998, 72.9% were culture-negative after 18 months. Because microscopy is a less sensitive method of detecting bacilli than culture, a higher proportion (82.1%) achieved sputum conversion by smear.

(c) Prevalence of tuberculosis

In 1999, 2 512 300 patients, former patients, and persons in high risk groups, were registered with MOH TB services. Remarkably, this is 1.7% of the Russian population, and 29 times the number of new cases reported in 1999. Among these, 357 088 patients (245 per 10^5 , 14.2%) were classified as having active disease (dispensary groups I, II, VA, VB). However, only 41% of these cases needed treatment, including new cases (87 258, 24.4%), relapses to active disease after cure (11 010, 3.1%) and active cases becoming sputum-positive (7576, 2.1%) or with fibrocavitary disease (34 043, 9.5%).

The prevalence of TB has been steadily increasing because incidence has been rising and treatment success falling. The ratio of prevalent/new cases with active disease (357 088/87 258) suggests the average period of follow up for groups I and II was *ca.* 4.1 years. Direct observation of patients in 1999 showed that adults with TB (in groups I and II, and other groups) were followed for 4.3 years on average. The period of follow-up was shorter for patients with (2.9 years) than without lung cavities (4.9 years), and for sputum-positive patients (3.3 years) as compared with sputum-negative disease (4.5 years).

Figure 5. Trends in the reported TB death rate. Series represent all TB deaths compiled by the Russian State Committee for Statistics, Goskomstat (filled circles), and deaths reported to the MOH TB services (open circles).

Figure 6. Annual changes in the TB death rate 1991–1999, with symbols as in figure 5.

(d) Deaths

The reported TB death rate has been increasing by an average of 11% per year since 1991, and reached 20.0 per 10^5 in 1999 (29 078 deaths, figure 5). As with case notifications, the rate of increase was quickest in the early 1990s, had stabilized by 1997 but accelerated again between 1998 and 1999 (figure 6). The pattern of growth was the same among permanent residents. The highest death rate in 1999 was among people aged 40–59 years (39.9 per 10^5). The reported death rate in children was 0.51 per 10^5 among those under five years, and 1.90 per 10^5 among infants (less than 1 year).

The case fatality rate among new cases reached a maximum of 4.0% in 1994–1995, but increased again in 1999 after 3 to 4 years of decline (figure 7). As case fatality rose during the early 1990s, so did the proportion of deaths occurring within 1 year of registration (figure 8). The change in case fatality rate is reflected in the growing proportion of cases reported with severe (fibrocavitary) disease (figure 8), and in the changing ratio of the number of patients cured to the number that died on treatment, which was 4.6 in 1987 and 1.8 in 1999.

Figure 7. Trends in the case fatality rate 1991–1999. Series are for new cases (open circles) and for all incident cases, including relapses (filled circles).

Figure 8. Trends in the proportion of new cases with severe (fibrocavitary) TB (filled circles) and in the proportion of all TB deaths that occurred among patients registered for 1 year or less (open circles).

(e) Tuberculosis in prisons

In 1999, the Ministry of Justice reported incidence rates of TB in prisoners (including detainees on remand) 40 times higher than in the general population (3447 per 10^5 compared with 85.2 per 10^5). The TB mortality rate among prisoners was over 100 times higher than in the general population (238 compared with 2.0 per 10^5).

Treatment outcomes were also worse in prisons. Of patients with lung cavities registered in 1998, only 45.5% had closed cavities by the end of 1999. The conversion rate (smear and culture) was 71.6%.

In 1999, 33 822 patients with active tuberculosis were released from prisons. Only 19 586 of these were registered by MOH TB services. Thus 42% of released patients, potential sources of infection, apparently received no further treatment.

(f) Quality of surveillance and laboratory data

Whilst there has been a steady increase in the number of reported cases over the past decade, two observations suggest that the fraction of cases detected has fallen, and that cases are being diagnosed less promptly and treated

Figure 9. Trends in active screening for TB (circles) and, consequently, the estimated infectious period (unmarked line). Active screening is a measure of the effort devoted to case detection and calculated as the percentage of the total population given a chest X-ray, a tuberculin skin test, or a sputum smear examination (circles). The relative infectious period was calculated from temporal changes in case detection and treatment failure rates (figure 4), as described in the text.

less effectively. First, only 57% of the total population was screened by X-ray in 1999, much lower than the high point of 75% in 1985 (figure 9). Second, as reported above (and in figure 8), the fraction of new cases with fibrocavitary TB, symptomatic of long diagnostic delays or perhaps low treatment efficacy, has been increasing since 1988, reaching 3.2% in 1999.

The relationship between infection and disease in children and adults calls into question the accuracy of case finding and diagnosis; both infection and disease are more difficult to diagnose in children. There was only a weak correlation ($r^2=61\%$) between the notification rate in children and in the whole population across the 11 territories of the Russian Federation. There was no correlation at all ($r^2=0.7\%$) between the reported notification rate of new cases among children and the incidence of first infection, as judged by tuberculin skin testing (2 units, induration ≥ 5 mm at first test).

The performance of bacteriology laboratories has also been declining. Mycobacteria were detected in 36.1% of all new patients registered in 1999, as compared with 45.0% in 1985, even though the disease was typically less severe during the 1980s. Among patients with positive sputum cultures, mycobacteria were found by microscopy in only 43.8% of sputum smears. In 1999, 4674 patients died of pulmonary tuberculosis without having been confirmed as bacteriologically positive.

Surveillance statistics included data on multidrug-resistant TB (MDR-TB, resistance to both isoniazid and rifampicin) for the first time in 1999. The proportion of all new sputum-positive cases with MDR-TB was 6.7%, but the recorded proportion varied from 1.3% in Ivanovo oblast to 47.1% in North Osetiya. There was no significant correlation between the proportion of patients with MDR-TB and treatment success (sputum conversion) across the 11 territories ($r^2=21\%$).

4. WHAT CAUSED THE RESURGENCE OF TUBERCULOSIS?

With these background data, we can begin to investigate whether TB incidence has risen because transmission has increased due to the failure of TB control services. The alternative is that transmission has increased for other reasons (e.g. migration, exchange of prison and civilian populations, crowding), or because infected people are now more likely to develop active disease (linked to malnutrition, alcoholism and stress). The truth is likely to be a mixture of the two. One approach to investigation is to ask whether observed changes in treatment success (figure 4) and case detection (figure 9) are sufficient to turn a decline in case notifications of 3.7% per year (1970–1990), into an increase of over 10% per year by 1992.

To capture the fundamentals of TB dynamics, we made a simple three-compartment mathematical model, similar in essence to that used by Dye *et al.* (1998):

$$\frac{dU}{dt} = \mu L + \varepsilon I - \lambda U, \quad (4.1)$$

$$\frac{dL}{dt} = (1-p)\lambda U - (\nu + px\lambda + \mu)L, \quad (4.2)$$

$$\frac{dI}{dt} = p\lambda U + (px\lambda + \nu)L - \varepsilon I. \quad (4.3)$$

The annual risk of infection is $\lambda = \beta I$, where β is the average infectious contact rate per year between an active TB case (I) and others in the population. The proportion of uninfected individuals (U) that develops active TB rapidly after infection (within 1 year in this model) is p ; the rest $(1-p)$ enter the latent class (L) where they break down to active disease at the much slower per capita rate of ν per year. The proportion of latently infected individuals that survives to develop active TB is $\nu/(\nu + \mu)$, where μ is the average death rate of people who do not have TB. Those with latent mycobacterial infection are assumed to be partially protected from developing active TB following reinfection; we denote x to be the fraction that is not protected. Lastly, ε is the rate at which active cases are eliminated, either by death or cure. The fractions $U + L + I = 1$, and the population is kept constant by recycling all infected people who died as uninfected births (equation (4.1)).

Guided by previous work (Sutherland *et al.* 1982; Vynnycky & Fine 1997; Dye *et al.* 1998), we set $p=0.1$, $\nu = 0.0001$ per year, $x=0.35$, with a life expectancy of 65 years ($\mu=0.0154$ per year; WHO 2000b). As an analytical convenience (which has no material effect on the conclusions), we assumed that TB incidence was stable in Russia in 1960, and then falling until 1991 because case detection and treatment had increased the removal rate of active cases (from ε to $\varepsilon + \Delta$), i.e. chemotherapy shortened the infectious period. (For the purposes of this exercise it does not matter whether we suppose that incidence was falling because of lower transmission or lower susceptibility.) The resurgence in TB incidence after 1991 was preceded by a fall in the effort given to case detection (from 1985, figure 9) and an increase in treatment failure

(from 1988, figure 4). The data in figure 9 suggest calculating a scalar, the relative case detection rate, $\delta(t)$, which declines from a maximum of 1.0 in 1985 to 0.79 in 1998. Similarly, figure 4 indicates that the relative failure rate (persistently positive sputum), $f(t)$, rose from 1.0 in 1982 to 2.53 in 1999. Combining these observations, we define the infectious period from 1985 onwards as $f(t)/[(\varepsilon + \Delta)\delta(t)]$, and this quantity takes a different value in each year up to 1999 (figure 9).

We fitted the incidence rates generated by this model to the series of case notifications for permanent residents, the data that have been collected in the most consistent way since 1970 (figure 1). The fit was carried out by numerically solving equations (4.1)–(4.3) (Euler method, time-step 1 year), and finding maximum likelihood estimates of the three unknowns β , ε and Δ (Williams & Dye 1994). The estimates, with standard errors (s.e.), were $\beta = 2.19$ (s.e. = 0.28), $\varepsilon = 0.17$ (s.e. = 0.02) and $\Delta = 0.043$ (s.e. = 0.006). With these parameter values the annual risk of infection, λ , was 0.4% in 1990, rising to 0.8% in 1999. When incidence was falling before 1990, each TB case was producing less than one new case in the following generation (case reproduction number less than one), but 2.9 new cases by 1999.

This model does not give an accurate representation of the data. The average rate of increase during the 1990s (8.4% per year) is about the same as observed (7.5% per year, figure 1), but the model epidemic rises too slowly from 1991–1995 and too quickly afterwards (figure 2). The rapid rise in reported cases from 1991 appears to be inconsistent with the view that failing TB control services were entirely to blame. Because the model exaggerates growth in incidence towards the end of the 1990s, the projection to 2005 is probably pessimistic (figure 1a, incidence 146 per 10^5). An alternative projection can be made by observing simply that the rate of increase in incidence among permanent residents had slowed to an average of ca. 5% per year by 1996–1999 (figure 2). Applying this growth rate gives an incidence of only 74 per 10^5 in 2005 (figure 1b).

Even though the dynamic model gives a poor explanation of the rise in caseload during the 1990s, it may be used to calculate the maximum possible gains to be made if improved treatment shortened the infectious period to its pre-1991 value. Despite changes in the prevalence of infection during the last decade, the model shows that the incidence rate would decline at 3–4% per year, as it did before 1991, but that will be an overestimate of impact if the growth in cases was not caused solely by an increase in transmission.

5. CONCLUSIONS

The resurgence of TB is among the most serious manifestations of the social and economic crisis in Russia. The 120 000 new cases (85 per 10^5) and nearly 30 000 deaths (20 per 10^5) reported in 1999 are probably underestimates of the true numbers because some institutions outside the Ministry of Health do not provide data to the MOH. Even with the uncertainties of surveillance data, it is clear that TB was the leading cause of death from an infectious or parasitic disease in 1999, accounting for an estimated 82% of all deaths from infectious agents. In the same

year, 1.4% of all reported deaths in Russia were associated with TB. The new outbreak has set TB control in Russia back 25 years.

The data describing the outbreak suggest that cases and deaths rose quickly at first, reaching maximum growth rates exceeding 18% in the years 1992–1993. The rate of increase slowed after 1993 so that the notification rate was growing at only 5% per year by 1998. The number of deaths had stabilized and even declined. Our mathematical model can replicate the average rate of growth in incidence during the 1990s but not the precise timing of the observed changes. The model produces an epidemic that grows too slowly from 1991–1995 and too quickly afterwards. The mismatch raises questions about the other factors, besides the failure of TB control services, that might have contributed to the resurgence. These include enhanced transmission due to immigration, crowding and the mixing of prison and civilian populations; an increase in susceptibility to disease; and rapid and unmeasured changes in the proportion of cases detected. On present evidence, we cannot say what role each of these factors has played over the past decade.

Whether a more comprehensive set of data describing transmission, used together with a more complex model, could represent the epidemiology more accurately remains to be seen. Meanwhile, the more reliable forecast of the epidemic is probably not from modelling but from a simple projection of case reports for 1996–1999. Assuming no change in the growth rate of case notifications, we expect to see roughly 74 new cases per 10^5 permanent residents in 2005. The TB death rate was roughly stable from 1996–1998; it increased sharply in 1999 only because of temporary drug shortages following the financial crisis of August 1998. It should therefore be feasible to push the death rate back under 15 per 10^5 within 1 to 2 years, and reduce it further thereafter.

If the current predicament cannot be explained solely by ineffective TB control, then it may not be possible to recover the previous rate of decline only by restoring TB control services. This, however, ignores the unexploited potential of improved diagnosis and chemotherapy. The 3–4% annual fall in incidence rate seen in Russia before 1991 was sluggish in comparison with what has been achieved in Western Europe, where over half of the total rate of decline of 10–12% per year has been attributed to chemotherapy (Styblo 1991; Dye *et al.* 1998).

Even without a full explanation for the recurrence of TB in Russia, our cross-examination of surveillance and laboratory data suggests a number of actions that can be taken immediately. The first is to restore prompt diagnosis of active disease in adults. The second is to raise the efficacy of treatment to its maximum (over 80% cure) and ensure a regular supply of drugs. Together these measures should cut the incidence of severe disease and reduce the death rate within the first few months of treatment. The third is to improve quality controls on bacteriological examinations in laboratories, including sputum cultures and smears. The fourth is to verify the diagnoses and classification (in dispensary groups) of infection and disease in children, and of extrapulmonary disease for which the rate of increase has been inexplicably slow over the past decade. It is difficult to identify new mycobacterial infections in children that have been vaccinated

with BCG. The fifth is to improve methods for measuring anti-tuberculosis drug resistance. The wide variation in MDR-TB rates between *oblasts*, and the lack of any association with treatment success, might be due to low frequencies of resistance (and hence small samples), or to unreliable laboratory procedures. The extent to which increases in treatment failures and deaths are linked to the spread of drug resistance remains unclear. The sixth is to ensure follow-up and continued treatment for TB patients released from prisons, as part of a programme of improved collaboration between the Ministries of Health and Justice.

All these measures are directed at curing a higher proportion of patients and reducing transmission because there is little chance of improving protection through increased BCG vaccination coverage. The vaccination rate among newborns in Russia, probably protecting against severe forms of childhood TB, has exceeded 90% in most years since 1990. Re-vaccination of older children, though common practice, is unlikely to prevent many more cases (WHO 2001).

Besides taking steps to improve the efficiency of the present system, a blend of economic and epidemiological research is needed to identify new practices that may be less costly or more cost-effective. With reference to the data above, we mention just two examples. The first concerns active case finding. X-ray screening adds to the number of TB cases that are diagnosed early, increases their chance of cure, probably reduces the number of medically complex and expensive treatments, and perhaps finds cases that would not otherwise be found. But the proportion of cases confirmed by bacteriology is low (12% by culture and/or smear), perhaps because early cases have less severe disease, or perhaps because cases are over-diagnosed by X-ray (which is sensitive but not specific). Also, because most individuals screened (e.g. in factories and offices) are healthy, the cost per case discovered is likely to be high. Notwithstanding the desirability of prompt diagnosis, a full analysis of costs and benefits (broad sense) is needed to identify the risk groups for which screening is justified.

Second, Russia has a high prevalence of TB partly because patients are followed for years as they move between numerous dispensary groups. The judgement that only 39% of cases with 'active disease' (groups I, II and V) require treatment, and the observation that over 2.5 million people were registered with TB services in 1999, should provoke a re-examination of the system of follow-up. A new investigation, building on the work of Bogadelnikova (1999), should explore the advantages and disadvantages of earlier hospital discharge, including ambulatory treatment for true active disease. Cost-effectiveness analysis might even lead to the proposition that some dispensary groups be eliminated (group II has already been abolished in five *oblasts*).

The implementation of such recommendations will need careful thought and wide discussion. For one thing, to scale down the information system will be to diminish the rich body of data that has allowed us to document, and propose remedies for, a major component of Russia's public health crisis.

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