Estimation of tuberculosis incidence and mortality in Egypt using epidemiological models

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تقدير معدل وقوع السل ووفياته في مصر باستعمال نماذج وبائية

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خلاصة: من أجل تقدير معدل وقوع السل في مصر، تم جمع بيانات من السجلات الوطنية للتبليغ عن إصابات الدرن، ومن إحصاءات تسجيل الوقائع الحيوية، ومن نتائج مسوحات التوبركولين ونتائج المعالجة. وكانت نتائج المسح الوطني الشامل بالتوبركولين من المصادر المهمة للمعلومات، حيث تم تقدير معدل لاكتشاف الحالات بلغ 55.2% ومعدل للإبلاغ عن الحالات بلغ 65.6%. وتدل البيانات على أن ثلثي الحالات الفعلية فقط هي التي يتم التعرف عليها ويعالج من قِبَل البرنامج الوطني. إن مقارنة الوفيات المتوقعة بالوفيات المبلّغة بسبب الدرن في مصر سنة 1996، توحي بأن هناك قصوراً في التبليغ عن الحالات يكاد يصل إلى 80%.

ABSTRACT To estimate tuberculosis incidence in Egypt, data were collected from national tuberculosis case notification records, vital registration statistics, tuberculin surveys and treatment outcomes. An important source of information was the national comprehensive tuberculin survey results, which estimated a 55.2% case detection rate and a 65.6% case notification rate. The data suggest that only two-thirds of actual cases are being identified and treated by the national programme. The figures for expected versus reported deaths from tuberculosis in Egypt in 1996 suggest underreporting to be almost 80%.

Estimation de l'incidence de la tuberculose et de la mortalité imputable à cette maladie en Egypte à l'aide de modèles épidémiologiques

RESUME Pour estimer l'incidence de la tuberculose en Egypte, des données ont été recueillies dans les registres nationaux de notification des cas de tuberculose, les statistiques d'état civil, les enquêtes tuberculiniques et les résultats des traitements. Les résultats de la vaste enquête tuberculinique nationale, laquelle a fourni une estimation du taux de dépistage de 55,2 % et du taux de notification des cas de 65,6 %, ont constitué une importante source d'information. Il ressort des données que seulement deux tiers des cas réels sont identifiés et traités par le programme national. Les chiffres des décès imputables à la tuberculose escomptés par rapport aux décès notifiés en Egypte en 1996 indiquent que la sous-notification est de presque 80 %.

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Introduction

Tuberculosis is a disease of significant public health importance worldwide. During the 1980s there was a gradual resurgence of tuberculosis, most notably in industrialized countries where it was thought the disease had been conquered, but also in the developing world [*1–3*]. In 1990, the number of people with tubercle bacilli infection was estimated to be 1.7 billion or approximately one-third of the world's population [*4*]. The World Health Organization (WHO) estimated that in 1999 there were about 8 million new cases of tuberculosis and 2 million deaths worldwide; the vast majority (95%) of these cases and 98% of deaths were in developing countries [*5,6*]. In the early 1990s, it was estimated that by 2000, the annual global number of new cases would have increased to over 10 million (163 per 100 000 population), and the annual expected number of deaths to 3.5 million per year (nearly 46 per 100 000 population) [*2,7*]. Globally, the targets set for tuberculosis control were that by 2000 the programme should have achieved successful treatment of 85% of smear-positive cases of pulmonary tuberculosis detected, and detection of 70% of existing cases of sputum smear-positive pulmonary tuberculosis [*8,9*].

The basic work on models for tuberculosis was undertaken by Styblo, whose model for estimating the magnitude of tuberculosis prevalence was based on assessment of infection in younger age groups, as measured through tuberculin surveys, and the observed fixed relation between the rate of annual risk of tuberculosis infection and the number of cases of smear-positive pulmonary tuberculosis. Several other epidemiological models have been developed using different parameters to measure different indicators.

The aim of the present study was to estimate the incidence of tuberculosis and the mortality resulting from it using globally adopted models and to suggest modification of the most suitable models to suit the Egyptian situation.

Methods

Data sources

The study used the following four different sources to obtain data.

- Case notification records. Available information about notified cases of tuberculosis by type [sputum smear-positive (SS+ve), sputum smear-negative (SS–ve) and extrapulmonary tuberculosis], age, sex and governorate was obtained from the Department of Statistics, Egyptian Ministry of Health and Population. Further data about the cases and treatment outcome were obtained from the National Tuberculosis Control Programme (NTCP).
- Vital registration statistics. Estimated population figures for Egypt for 1996 were obtained from the Central Administration for Population, Mobilization and Statistics (CAPMAS).
- Tuberculin surveys. The results of the two comprehensive tuberculin surveys carried out in Egypt in 1952 and in 1995 were used in this study (Ministry of Health and Population, unpublished reports). Both were carried out using a representative sample of districts all over Egypt and on school-attending children aged 6–7 years old. It is fortunate that both surveys were carried out in the same districts using the standard methodology adopted by WHO and the International Union Against Tuberculosis and Lung Diseases.

- Information on treatment outcome. This information was obtained from treatment units that keep records.

Efforts were made to uncover any prevalence surveys carried out in Egypt. Unfortunately, no published or unpublished information on such surveys could be found at either the Ministry of Health and Population or at the NTCP.

Estimation of incidence and mortality

Five different methods of estimating incidence and mortality of tuberculosis in Egypt were used.

- The Styblo method [*3,10*], which uses the results of tuberculin surveys in young age groups (usually ages 5–9 years) to determine the prevalence of infection. From this, the annual risk of tuberculosis infection (ARTI) is calculated.
- Prevalence method [*11*], which is based on data on the prevalence of tuberculosis.
- The death method [*11*], for which the starting point is registered deaths by age and sex and to which a correction factor for underregistration is applied.
- The Dolin et al. method [*12*], which is based on the use of notification data, to which a correction factor for underreporting and relapse is applied.
- The Mexico model [*11*], which is based on both registered deaths and notification data.

In view of the inadequacy of reasonably accurate, complete information on deaths in Egypt and the often inaccurate determination and reporting of underlying cause of death (particularly in deaths occurring outside hospitals) [*13*], it was decided to avoid the use of models that depend on mortality data, and restrict the work to models based on morbidity data.

The Styblo model was considered the most suitable as it depends on ARTI, which has recently been calculated with a great degree of accuracy in Egypt. Styblo data provide a reasonable estimate of underreporting, probably the best estimate from which the correction factor for underreporting is calculated.

According to the WHO-modified Styblo model:

- the estimated number of SS+ve cases = ARTI × 70/100 000 × population;
- the estimated number of SS–ve cases = the estimated number of SS+ve cases (Sudre et al. [*3*]);
- the total number of extrapulmonary tuberculosis cases = 0.22 × SS+ve (Sudre et al. [*3*]);
- the estimated total number of cases = SS+ve + SS–ve + extrapulmonary cases;
- the notification rate = (number detected/number estimated) × 100;
- the case detection rate = (number of SS+ve notified/estimated number SS+ve) × 100.

Two computer programs were developed. They were written in Q basic language and were both based on the Styblo model with modification to suit the Egyptian situation. The first program was used for estimating the incidence and under- and overreporting of various types of tuberculosis. The second program was used to estimate tuberculosis-associated mortality by comparing alternate treatment models. It was based on the annual cohort of tuberculosis incidence and the assumption that within 5 years of contracting the disease there would be:

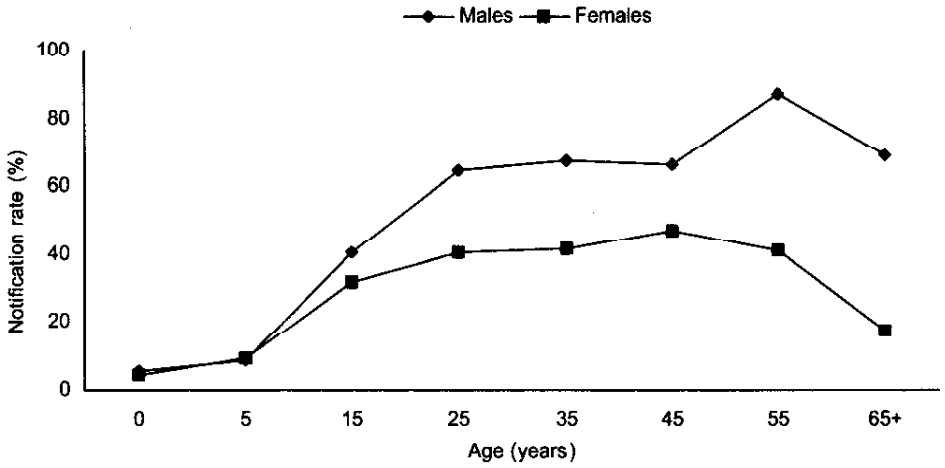

Figure 1 **Case notification rates of tuberculosis by age and sex, Egypt 1996.**

- 50% mortality among the cases not treated at all;
- 20% mortality among cases inadequately treated;
- 15% mortality among cases receiving ordinary programme treatment;
- 7% mortality among cases receiving directly observed treatment, short-course (DOTS).

Table 1 **Distribution of notified cases of tuberculosis in Egypt by type and age, 1996**

Age group (years)	Pulmonary			Extrapulmonary		Total no.
	SS+ve No.	SS–ve No.	Ratio of SS–ve to SS+ve	No.	%	
0–	53	213	4.02	133	33.3	399
5–	202	675	3.34	457	34.3	1334
15–	1712	1648	0.96	875	20.7	4235
25–	2020	1947	0.96	696	14.9	4663
35–	1472	1552	1.05	531	14.9	3555
45–	1035	1263	1.22	340	12.9	2638
55–	662	1027	1.55	223	11.7	1912
65+	289	498	1.72	130	14.2	917
Total	7445	8823	1.19	3385	17.2	19653

SS+ve = sputum smear-positive.
SS–ve = sputum smear-negative.

Table 2 **Treatment outcome for new smear-positive cases of pulmonary tuberculosis, Egypt, 1996**

Outcome	No.	%
Cured	1266	47.92
Completed treatment	540	20.44
Treatment failure	115	4.35
Defaulted	413	15.63
Transferred to a different catchment area	257	9.73
Death	51	1.93
Total	2642	100.00

Table 3 **Tuberculosis mortality rates by age and sex per 100 000 population, Egypt, 1992**

Age group (years)	Males	Females	Total
0–	0.837	0.419	0.634
5–	0.324	0.370	0.346
15–	0.832	0.936	0.883
25–	2.544	1.867	2.215
35–	3.312	2.291	2.812
45–	5.639	4.161	4.905
55–	12.071	4.041	7.922
65+	15.652	5.532	10.271
Total	2.625	1.605	2.125

Results

Tuberculosis information in Egypt

Case notification records

Figure 1 presents the case notification rates by age and sex. It is clear that the number of reported cases is lowest for the < 15 years age group. It then increases sharply after age 15 years, remains at roughly the same high rate for the age groups 25–64 years, and then decreases among those ≥ 65 years. The same pattern is observed in both males and females. However, from ages ≥ 15 years, figures for females are lower than those for males.

Differences by age and sex were also studied in relation to the type of tubercles (Table 1). In the young age groups (< 15 years), the proportion of extrapulmonary cases was much higher than in age groups ≥ 15 years. The proportion diagnosed with pulmonary tuberculosis through smears was much lower in the young age groups, particularly in the groups < 5 years.

Treatment outcome

In 1996, 2642 new smear-positive cases received treatment through NTCP. The treatment outcome is shown in Table 2. It suggests that fewer than half the cases were cured. Another 20% of cases took the complete course of treatment with a negative smear at the end of the initial phase, but with no, or only one, negative sputum examination in the continuation phase. The defaulter rate was quite high — nearly one in every seven patients defaulted after registration.

Mortality data

The latest available data on deaths from tuberculosis by age and sex and type of tuberculosis is that of 1992 (unpublished). Table 3 shows death rates by age and sex. The lowest mortality appears to be in the 5 15-year age group. No difference in mortality pattern is observed between males and females. Generally speaking, mortality among females is lower than that of males

- Estimated number of SS+ve cases = ARTI × 70/100 000 × population = 13 493.
- As the number of SS+ve cases notified and detected in 1996 was only 7445 (Table 1), then the case detection rate = 55.2%.
- Estimated number of SS–ve cases = estimated number of SS+ve cases (Sudre et al. [*3*]), therefore, the number of expected SS –ve cases will be 13 493.
- The total number of cases of pulmonary tuberculosis = the number of SS + ve cases + number of SS – ve cases = 26 986.
- The estimated number of cases of extrapulmonary tuberculosis (according to Sudre et al. [*3*]) = 0.22 × the estimated number of SS+ve cases = 0.22 × 13 493 = 2968, which is lower than the number reported.
- The estimated total number of cases = SS+ve + SS–ve + extrapulmonary = 13 493 + 13 493 + 2968 = 29 954.
- The notification rate for all cases = (number detected/number estimated) × 100 = 19 653/29 954 × 100 = 65.6%.

Box 1 **Estimated figures for tuberculosis in Egypt**

in each age group, except in the two age groups, 5–14 years and 15–24 years, where the rates are slightly higher for females than males.

Application of the Styblo model

The results of the 1995 tuberculin survey carried out in Egypt on 61 000 school children aged 6 and 7 years indicated that the average ARTI was 0.32% [*14*]. Applying the Styblo formula (for every 1% annual risk of tuberculosis infection there are nearly 50 cases per 100 000 population of SS+ve pulmonary tuberculosis), the rate of 0.32% indicates 16 sputum-positive cases of pulmonary tuberculosis per 100 000 population, or an expected number of 9600 SS+ve cases among Egypt's population of approximately 60 million. Comparing this number with the number detected by the national health care system (7445) suggests that approximately three-quarters (77.5%) of the SS+ve cases are being detected by the national health care system in Egypt, with an additional percentage treated in the private health care system.

According to WHO's global tuberculosis control programme, to obtain the incidence of SS+ve cases by the Styblo model in situations where tuberculosis is on the decline, it is necessary to multiply by a number larger than that of the Styblo model

Table 4 **Estimated tuberculosis mortality rates over a 5-year period by treatment schedule, Egypt**

Treatment schedule	Mortality rate (%)				
	Year 1	Year 2	Year 3	Year 4	Year 5
No treatment	25	20	10	5	1
Poor treatment	10	5	3	2	1
Classical treatment	8	4	2	1	0.5
DOTS	5	1	0.5	0.5	0

DOTS = directly observed treatment, short-course.

Table 5 **Estimated tuberculosis mortality among the 17% of detected cases who received DOTS, Egypt, 1992–96**

Year	Incidence No.	Mortality No.	Probability of death				
			Year 1 0.05	Year 2 0.01	Year 3 0.005	Year 4 0.005	Year 5 0.00
1992	0		0.00	0.00	0.000	0.000	**0.00**
1993	0		0.00	0.00	0.000	**0.000**	0.00
1994	0		0.00	0.00	**0.000**	0.000	0.00
1995	3341		167.05	**31.74**	15.710	15.630	0.00
1996	3341	**199**	**167.05**	31.74	15.710	15.630	0.00

DOTS = directly observed treatment, short-course.

(50/100 000). This is because ARTI declines more quickly than the incidence [*15*]. In such situations, multiplication by approximately 70/100 000 for every 1% ARTI will give a more reasonable estimation of the number of SS+ve cases. Using the above models, the estimated figures for tuberculosis in Egypt are shown in Box 1.

Estimation of mortality using cohort of tuberculosis incidence

A computer program based on annual cohorts of tuberculosis over a 5-year period was used to estimate the number of tuberculosis-associated deaths for Egypt. Several scenarios were applied. Table 4 shows the assumptions made for the mortality rates for the 5-year period based on published information on case fatality rates in relation to treatment [*15,16*].

Possible scenarios for what is occurring in Egypt are as follows.

- The cases of tuberculosis detected by the NTCP (19 653) are divided into two groups: the first group (17%) receiving DOTS and the group (83%) receiving the classical programme treatment (not DOTS).
- The cases not discovered by the programme (10 301) are assumed to be divided equally, 50% receiving some treatment and 50% receiving no treatment.

Table 6 **Estimated tuberculosis mortality among the 83% of detected cases who received the classical treatment, Egypt, 1992–96**

Year	Incidence No.	Mortality No.	Probability of death				
			Year 1 0.08	Year 2 0.04	Year 3 0.02	Year 4 0.01	Year 5 0.005
1992	19653		1572.24	723.23	347.15	170.10	**84.20**
1993	19653		1572.24	723.23	347.15	**170.10**	84.20
1994	19653		1572.24	723.23	**347.15**	170.10	84.20
1995	16312		1304.96	**600.28**	288.14	141.19	69.89
1996	16312	**2507**	**1304.96**	600.28	288.14	141.19	69.89

Table 7 **Estimated tuberculosis mortality among half the estimated undetected cases who are assumed to have had out-of-programme treatment, Egypt, 1992–96**

Year	Incidence No.	Mortality No.	Probability of death Year 1 0.1	Year 2 0.05	Year 3 0.03	Year 4 0.02	Year 5 0.01
1992	5150		515.00	231.75	132.10	85.42	**41.86**
1993	5150		515.00	231.75	132.10	**85.42**	41.86
1994	5150		515.00	231.75	**132.10**	85.42	41.86
1995	5150		515.00	**231.75**	132.10	85.42	41.86
1996	5150	**1006**	**515.00**	231.75	132.10	85.42	41.86

Table 8 **Estimated tuberculosis mortality among half the estimated undetected cases who are assumed not to have received any treatment, Egypt, 1992–96**

Year	Incidence No.	Mortality No.	Probability of death Year 1 0.25	Year 2 0.2	Year 3 0.1	Year 4 0.05	Year 5 0.01
1992	5150		1287.50	772.50	309.00	139.05	**26.42**
1993	5150		1287.50	772.50	309.00	**139.05**	26.42
1994	5150		1287.50	772.50	**309.00**	139.05	26.42
1995	5150		1287.50	**772.50**	309.00	139.05	26.42
1996	5150	**2534**	**1287.50**	772.50	309.00	139.05	26.42

Applying the mortality rates outlined in Table 4, among those receiving DOTS there will be 199 deaths (Table 5), and among those receiving the classical programme treatment, there will be 2507 deaths (Table 6). With the second scenario, among those receiving out-of-programme treatment (Table 7) there will be 1006 deaths, and among those receiving no treatment (Table 8) there will be 2534 deaths. Total deaths will thus be: 199 + 2507 + 1006 + 2534 = 6246, with underreporting in case notification of more than 40%, and underreporting of mortality almost 80%.

Discussion

Tuberculosis continues to be an important public health problem in Egypt. To put the disease in proper perspective, it is essential to have accurate information on the morbidity and mortality resulting from the disease. It has been given special attention in the last few years with the revitalization of the NTCP, which is proceeding gradually to implement the globally accepted strategies for tuberculosis control.

Some of the principal factors responsible for the resurgence of tuberculosis throughout the world are less prevalent in

Egypt. The incidence of human immunodeficiency virus infection is still low [*17*], socioeconomic conditions are improving and the national authorities are giving priority to the programme. However, there is evidence that current levels of case notification significantly underestimate the real occurrence. The number of cases of tuberculosis notified through the programme in 1996 was 19 653 (7445 SS+ve, 8823 SS–ve and 3385 extrapulmonary). This compares with the 29 954 cases (13 493 SS+ve, 13 493 SS–ve and 2968 extrapulmonary) estimated for the same period by our study.

A significant cohort of cases is not accessing the services of the NTCP. This cohort includes those seeking treatment from the private sector (believed to be a substantial number) and those receiving health care through university hospitals and special health care services (e.g. armed forces and other governmental and public sector medical services). Inadequacies in health data collection and dissemination in Egypt make it unlikely that information obtained on tuberculosis morbidity and mortality will be accurate. Indirect methods of estimating the magnitude of tuberculosis are therefore necessary, and are in wide use. Applying the Styblo model with the WHO-recommended modification to suit the epidemiological situation in Egypt, the expected number of SS+ve tuberculosis cases for 1996 was 13 493, and the estimated total number of cases was 29 954, giving an incidence of about 50/100 000 for all tuberculosis cases. This is double the lowest incidence for developing countries (25/100 000), but only one-fifth the highest incidence for developing countries (240/100 000). Comparing estimated cases (13 493) to reported cases (7445) suggests a case detection rate of 55%, much lower than the 70% target set by the Global Tuberculosis Control Programme [*18*].

Ministry of Health and Population data showed 1.2 times as many SS–ve cases as SS+ve. This may be due to flawed laboratory diagnosis of pulmonary tuberculosis cases, with some of the SS+ve cases being missed, and some misdiagnosed as SS–ve.

The ratio of extrapulmonary tuberculosis to SS+ve reported by the programme was higher than expected (0.45 compared to 0.22 reported by several studies [*5*]). This may also be due to the lower rate of pulmonary tuberculosis reported by the national programme.

The distribution of notified cases of tuberculosis by age shows that, unlike other age groups, for the age groups < 5 years and 5–15 years the ratio of SS–ve to SS+ve is high. This is simply because young children are unable to produce sputum for examination. Mortality data for 1992 (the latest available information) showed mortality decreased after the age of 5 years to be lowest in the age group 5–15 years, thereafter gradually increasing with age. This is consistent with the global epidemiology of tuberculosis published by WHO [*18*].

Using our computer program, we calculated the number of deaths that would be expected among the reported cases [*18*]. The number of deaths reported (1275) is much lower than the estimated number of 6246. A possible reason is the fact that, apart from deaths that occur in hospitals or in other government institutions, the underlying cause of death may not be recorded accurately. In addition, in view of the stigma attached to tuberculosis, there may be a tendency to cover up these cases and report them as chronic bronchitis. The differences between the number of deaths

reported and the number expected show that underreporting is significant, and indicate that only one in every five or six deaths due to tuberculosis is being recorded accurately.

Real decreases in tuberculosis mortality will occur when the NTCP is able to either directly treat all cases of tuberculosis in Egypt, or at least influence the method of treatment applied in private practice and other health care services, such as university hospitals and military medical services. If the national programme can achieve its target of DOTS for all by 2000, it will have had a real impact on the problem of tuberculosis — more immediately on incidence and mortality rates, but also in the longer term, on prevalence.

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EMRO tuberculosis website

WHO EMRO now has a tuberculosis website which provides wide-ranging information on the disease, including general information, current epidemiological data for each country of the Region, a regional bibliography and a list of current and planned activities related to tuberculosis control. The site also includes a forum for discussion for users interested in exchanging thoughts and dialogue on tuberculosis issues. The site can be accessed at:

http://www.emro.who.int/stb