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Original Article

Prediction of the Epidemiological Situation of Tuberculosis in Slovakia by 2040- Data Update

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Abstract

Background: Despite the available diagnostics and treatment, tuberculosis (TB) is a serious infectious disease currently occurring. Even some high-income countries in the world do not fully control it at this time. The reason for this situation is the lack of elimination programs to address the situation. The aim of the update of the prediction data was to create a presumption of TB development in Slovakia by 2040.

Methods: We used the time series prediction method with exponential equalization. The basis for the calculation were historical data on the incidence of TB from 1960 to 2018 in Slovakia (data for the last 58 yr). This time series has a clearly declining level. In view of this trend, we have set a threshold, whether and when the incidence in the future will fall below 5.0 patients per 100,000 inhabitants.

Results: In case of a favorable development, the limit of our incidence drop below 5.0 cases per 100 000 inhabitants in 2022, when the incidence will be 4.91 per 100 000 inhabitants. In 2040, the predicted incidence of TB should be 1.78 per 100 000 inhabitants. A gradual decline may also be related to a decrease in the population of the Slovak Republic.

Conclusion: Slovakia belongs to those countries of the world where TB is under control. Increased surveillance of high-risk communities through community interventions and countries' readiness for global migration can help to influence factors that may aggravate the epidemiological situation of TB.

Keywords: Tuberculosis; Incidence; Epidemiological situation; Time series prediction

Introduction

In many cases, people with tuberculosis (TB) live in places where health care and education are not adequately available. TB is spreading in communities, homes, segregated settlements, and blocks of urban dwellings - places with high concentration of people. TB also brings other complications that prevent people with typical symptoms from seeking professional help - stigmatization in the general population, but also in healthcare professionals. There is strong evidence that TB flourishes in poverty, but it also brings several pitfalls. To speak of TB only as a social disease

could paradoxically be harmful. Linking social nature to disease could indicate that eradicating poverty will also eradicate TB. Only few studies showed that social intervention affects the transmission and incidence of TB. The link between TB and poverty is the driving force in community stigmatization (1, 2).

The nature of stigma and TB (including interventions to help reduce the impact of stigmatization and TB), including in low-incidence countries, needs to be mapped by adopting conceptual frameworks that provide a better understanding of how stigma affects the social status of individuals (3). Given the unsatisfactory success of TB removal, the society used the social paradigm as a pretext for lack of activity in the fight against the disease. The emergence of drug resistant TB is iatrogenic and suggests that current approaches to TB treatment in biomedicine and public health are failing. We know how to use paradigms, diagnose and have medicines from the last century. We need a shift more effort to TB: it's urgent (4).

Risk groups

Some population groups are more susceptible to TB. Often, they are people who are disadvantaged by other ways, making them less able to cope with the consequences of TB (5):

- Poor - many poor people are forced to live in crowded flats, increasing the risk of TB transmission.
- Migrants - often because of poor eating habits and living conditions, an active disease develops on arrival in a new country. Limited access to health services in their adoptive country can prevent migrants from early diagnosis and treatment.
- Refugees, displaced persons and people living in shelters - are often exposed to risk factors due to instability, uncertainty and physical collapse of social and health infrastructure, malnutrition, stress and lack of access to early diagnosis and treatment. It is also the result of poor housing conditions, especially overcrowding, which increases the spread of TB and other respiratory diseases. There is also a high mortality rate, especially among migrant women and children.
- Homeless - represent the most vulnerable group of TB.
- Prisoners - are at risk of contracting TB due to overcrowding and poor diet.
- People living with HIV / AIDS - TB is the most common cause of death in people infected with HIV. At least 1 in three people infected with HIV are infected with TB during their lifetime.
- For some diseases, the risk of TB disease is increased - e.g. alcoholism increases the risk of the disease four times, diabetes mellitus and malnutrition also four times, gastrectomy and hemodialysis five times, hemophilia ten times, immunosuppressive therapy twelve times, silicosis thirty times and HIV positivity 100 times (6).
- Elderly population - At present, 14.45% of people in Slovakia are 65 yr old or older. According to predictions, in 2060 every third inhabitant in Slovakia will be at least 65 yr old. A very important demographic feature is also the growth of the group of "very old people", thus the so-called double aging. The "double aging" process means that more people are living longer while fewer children are born, resulting in an increase in the median age (7).

The aim of the update of the prediction data was to create a presumption of TB development in Slovakia by 2040.

Methods

In the calculations, we used the method of predicting time series with exponential compensation. This method is the most widely used prognostic method for its computational simplicity and, above all, for its ability to react quickly to recent changes in time series values. The methodology takes into account the past development of the monitored quantity using its weighted av-

erages. STATGRAPHICS Centurion XV statistical software was used for calculations. The basis for the calculation was the historical data on the incidence of the disease from 1960 to 2018. This time series has a clearly declining level, when in 1960 the incidence was 164.1 patients per 100,000 inhabitants.

At the turn of the millennium, there were only 20 patients per 100,000 inhabitants. The latest data from 2018 represent only 5.18. Given this trend, we have set a limit that interested us and whether and when the incidence will fall below 5.0 patients per 100,000 population in the future. We decided to predict the development of this quantity until 2040 - so 22 yr were predicted. To illustrate the accuracy of the method used, the results of the prediction are presented together with historical data, where we see the predicted value of the model and its deviation from the real value for each year.

Results

Based on the processing of data from the National Register of TB patients and Infostat, we processed the obtained data in the first step by the method of one-dimensional descriptive statistics. We used frequency tables to describe the categorical variable.

First prediction

From the results in Table 1 and 2 we can see that the series showed further decreasing character. In 2020, the incidence of TB will be 5, 49 per 100,000 inhabitants, representing 297.27 patients. We also saw that the incidence threshold we set is 5.0 by 2022. Our findings indicated an incidence rate of 4, 91 per 100,000 inhabitants in 2022 (265.33 patients). In 2038, we can even get under 2 sick patients per 100,000 inhabitants. The number of TB patients in a given year will be 106, 88 patients.

Table 1: Model: exponentially balanced time series prediction

Year	*Data*	*Prediction*	*Deviation*
1960	7817	161,85	2,25
1961	6620	152,98	-22,68
1962	6553	144,59	-22,19
1963	6278	136,66	-21,16
1964	5837	129,17	-24,87
1965	5848	122,09	-18,99
1966	5989	115,39	-6,09
1967	6253	109,06	5,24
1968	6236	103,08	12,62
1969	5891	97,43	11,77
1970	5764	92,09	14,71
1971	5294	87,04	10,56
1972	4584	82,27	0,33
1973	4190	77,76	-3,16
1974	4015	73,49	-2,19
1975	3759	69,46	-3,46
1976	3694	65,65	-2,25
1977	3401	62,05	-5,05
1978	3163	58,65	-5,25
1979	3010	55,44	-4,64
1980	2896	52,40	-2,90
1981	2739	49,52	-3,62

1982	2679	46,81	-2,01
1983	2664	44,24	-0,04
1984	2535	41,82	0,18
1985	2330	39,52	-1,02
1986	2022	37,36	0,24
1987	1830	35,31	-1,91
1988	1647	33,37	-2,07
1989	1492	31,54	-3,34
1990	1445	29,81	-2,51
1991	1624	28,18	2,42
1992	1722	26,63	5,77
1993	1795	25,17	8,43
1994	1748	23,79	8,91
1995	1538	22,49	6,21
1996	1499	21,25	6,55
1997	1296	20,09	4,01
1998	1282	18,99	4,71
1999	1218	17,95	4,65
2000	1111	16,96	3,64
2001	1078	16,03	3,97
2002	1053	15,15	4,45
2003	973	14,32	3,88
2004	705	13,54	-0,44
2005	743	12,79	1,01
2006	732	12,09	1,51
2007	708	11,43	1,77
2008	652	10,80	1,27
2009	513	10,21	-0,72
2010	443	9,65	-1,48
2011	399	9,12	-1,78
2012	345	8,62	-2,27
2013	401	8,15	-0,74
2014	336	7,70	-1,50
2015	317	7,28	-1,43
2016	296	6,88	-1,43
2017	249	6,50	-1,92
2018	281	6,15	-0,97

Second prediction

Subsequently, we were also interested in the situation of a narrower, specific category of patients, namely children. We have data on the population aged 0-19. We have historical data for the last 12 yr (from 2007 to 2018). The specific situation in this group of patients was due mainly to the fact that the vaccination obligation in children has been abolished recently.

Reflection of this measure can be seen in the increasing incidence trend in pediatric patients. We predicted 5 yr ahead due to the relatively small period for which we have historical data. The following Table 3 shows historical data supplemented by the forecast for 2019 to 2023.

Table 2: Incidence prediction of TB

Prediction			*Incidence*	*Lover range limit*	*Upper range limit*
Year	Population	Predicted number of patients			
2019	5416162	314,65	5,81	4,13	8,16
2020	5413779	297,27	5,49	3,91	7,72
2021	5411406	280,85	5,19	3,69	7,30
2022	5409046	265,33	4,91	3,49	6,90
2023	5406679	250,67	4,64	3,29	6,53
2024	5404302	236,82	4,38	3,11	6,18
2025	5401947	223,74	4,14	2,94	5,84
2026	5399581	211,38	3,91	2,77	5,52
2027	5397208	199,70	3,70	2,62	5,23
2028	5394846	188,67	3,50	2,47	4,94
2029	5392491	178,25	3,31	2,34	4,67
2030	5390133	168,40	3,12	2,21	4,42
2031	5387757	159,09	2,95	2,08	4,18
2032	5385404	150,31	2,79	1,97	3,96
2033	5383047	142,00	2,64	1,86	3,74
2034	5380682	134,16	2,49	1,76	3,54
2035	5378302	126,74	2,36	1,66	3,35
2036	5375961	119,74	2,23	1,57	3,17
2037	5373617	113,13	2,11	1,48	3,00
2038	5371270	106,88	1,99	1,40	2,83
2039	5368881	100,97	1,88	1,32	2,68
2040	5366576	95,39	1,78	1,25	2,54

Table 3: Incidence prediction of TB in 0 – 19 yr old population

Year	*Data*	*Prediction*	*Deviation*
2007	30,00	34,03	-4,03
2008	23,00	32,42	-9,42
2009	21,00	20,46	0,54
2010	17,00	18,14	-1,14
2011	29,00	13,60	15,40
2012	27,00	33,23	-6,23
2013	49,00	29,08	19,92
2014	57,00	60,65	-3,65
2015	72,00	68,07	3,93
2016	66,00	84,81	-18,81
2017	54,00	69,65	-15,65
2018	40,00	48,65	-8,65
		Lower 95,0% Lover limit 95,0%	Upper 95,0% Upper limit 95,0%
2019	42,32	20,54	64,10
2020	35,99	16,97	54,99
2021	29,66	11,76	36,51
2022	23,33	9,46	23,96
2023	17,00	5,08	17,05

Discussion

In 2017, more than 280 000 cases of tuberculosis were reported in the WHO European Region. TB remains a major public health problem in the European region of the WHO, including the countries of the European Union / European Economic Area (EU / EEA). Epidemic patterns and trends vary considerably approaching a low incidence rate of 10 per 100,000 inhabitants in EU / EEA, but nine out of 30 countries in the region are exposed to multiple drugs resistant forms of tuberculosis (Fig. 1).

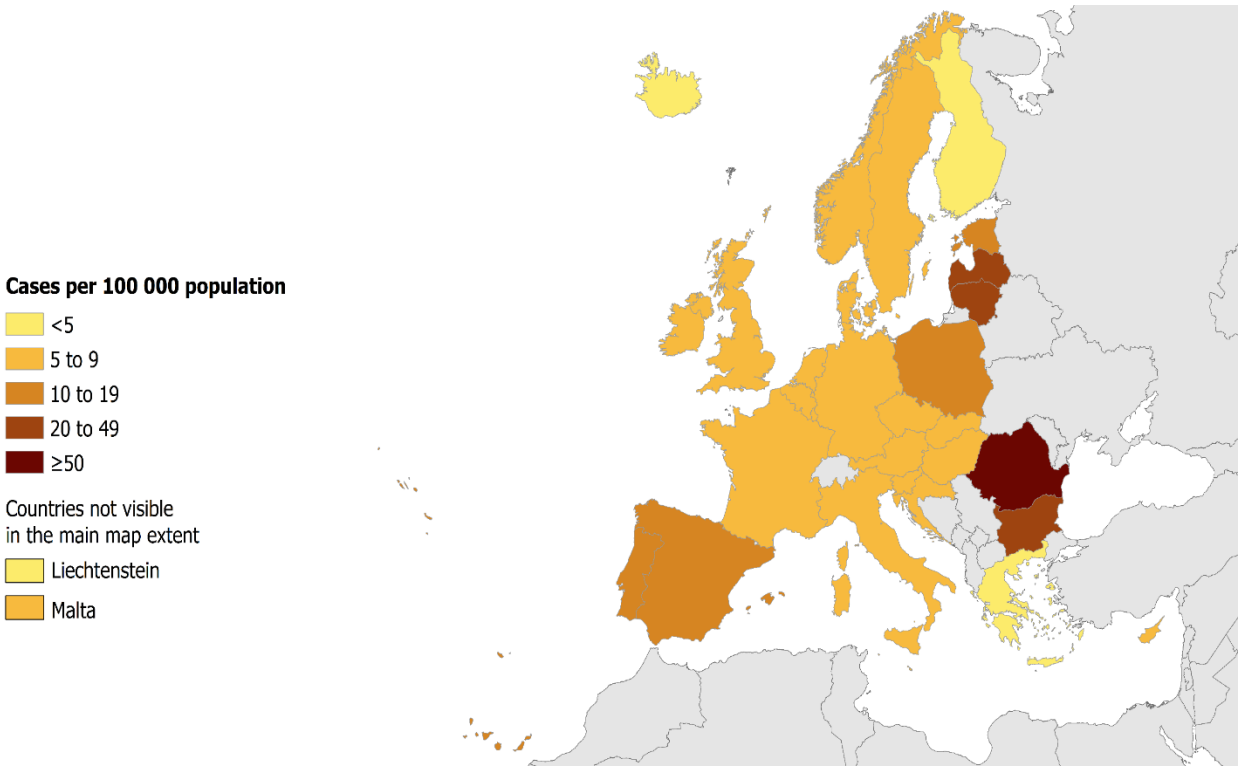

Fig. 1: Number of TB cases per 100 000 inhabitants EU/EEA in 2017 (8)

Overall, TB mortality and incidence rates decreased. Despite considerable progress, countries still face different challenges. In 2017, 55,337 cases of TB were reported in 31 countries of the European Union and the European Economic Area (EU / EEA), resulting in rate of 10.7 per 100,000 inhabitants. The overall notification rate in most countries have been decreasing over the last five years. Of all the notified cases of TB were newly diagnosed 39,903 (72.1%) and 37,700 (68.1%) were confirmed by culture or nucleic acid amplification test. In general, adult age groups had a higher rate of notification of new and relapsed TB than children under 15 yr of age. Children under 15 yr represented 4.4% of all new and relapsed TB cases, corresponding to a notification rate of 2.9 per 100,000 inhabitants. The highest rates between 0 and 4 yr of age were recorded in Bulgaria and Romania. For one case diagnosed in a woman, there are two cases in a man. 33% of all cases of TB reported in the EU / EEA were of foreign origin. Multidrug-resistant tuberculosis (MDR-TB) has been reported in 1,041 (3.8%) of the 27,339 cases with relevant drug sensitivity results - DST and remains highest (over 10%) in the three Baltic states. X-drug re-

sistant tuberculosis (XDR-TB) was reported in 24.3% of the 770 cases of MDR-TB tested for the second drug sensitivity line. After remaining at 0.3 per 100 000 inhabitants from 2013 to 2016, the number of reported cases of MDR-TB decreased to 0.2 in 2017. However, it should be noted that more than 45% of these cases of pulmonary XDR-TB have been reported from Lithuania and Romania. Although the number of countries reporting HIV co-infection data has increased from 2016 to 2017, the data remains incomplete. Of all TB cases with reported HIV status, 3.9% were co-infected with the virus. TB in prisons is still poorly reported. For the 15 EU / EEA reporting Member States, the notification rate was 155 new cases and relapses of TB per 100 000 prisoners (8).

Current situation in Slovakia

Slovakia is one of the most successful countries in terms of health protection against TB. Despite the high standards of treatment and prevention procedures for the deterioration of socio-economic conditions, there is an increase in the incidence of TB in risk groups that need to be controlled (9).

In 1960, 7817 cases of TB were registered. According to data from the National TB Register, the absolute number of reported diseases decreased by 1970. In the second half of the 1980s the decline was even more pronounced. In 2002, 1,053 cases of newly diagnosed TB were reported, and in 2003 for the first time, the number of newly detected cases was less than 1,000. Nowadays the situation in Slovakia is stabilized. In 2018, 281 cases of TB were reported to the National TB Registry, which is 5.18 / 100 thousand. There were 75 cases of Roma origin (26.69%). Totally, 244 cases of pulmonary TB and 37 cases of non-pulmonary TB. There were 21 relapses of TB in 2018. In the pediatric population, the disease occurred in 40 cases. As many as 87.5% (35 cases) were children of Roma origin. One case of TB and HIV co-infection was reported in 2018. According to geographical distribution in the Slovak Republic, the worst area with the highest incidence of this disease is the region of Košice 10.26 / 100 thousand residents. The lowest incidence is recorded in the Trnava and Banská Bystrica regions (Fig. 2) (10).

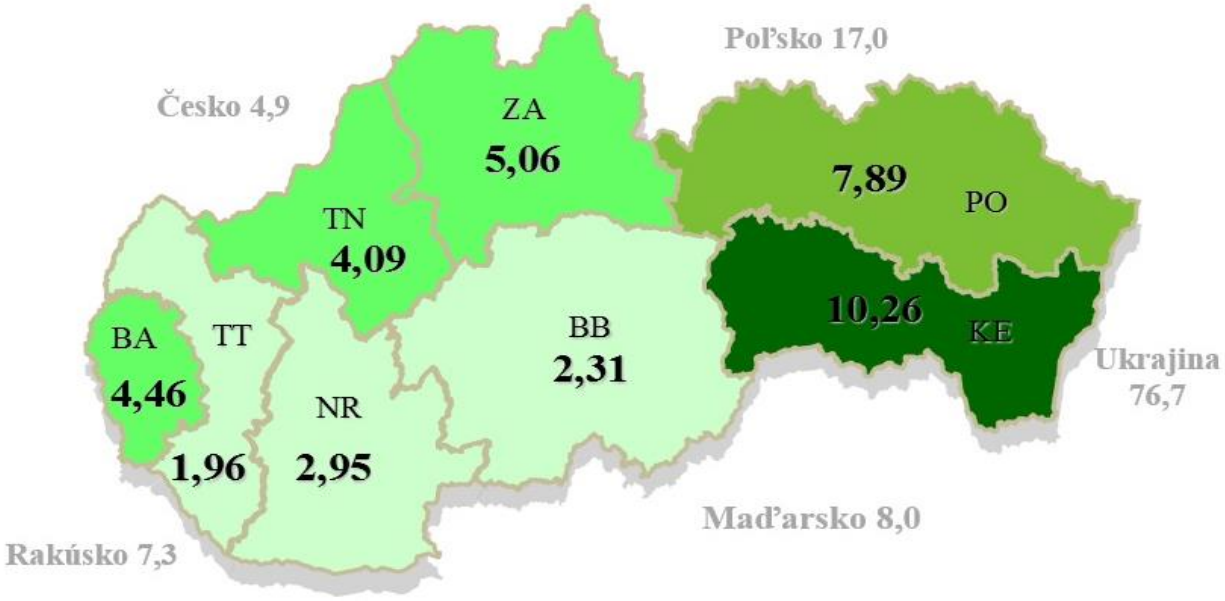

Fig. 2: TB situation in Slovakia (10)

The main objective was to create a trend analysis of TB incidence in the Slovak Republic. The research part of the work focused on monitoring the development of TB incidence taking into account the incidence from 1960 to 2018. The values were based on data from the National TB Patient Register and the development of the incidence by 2040 was predicted. The work compared the situation in Slovakia and the predicted time when we reach the incidence of disease below the threshold of 5 patients per 100 000 inhabitants. We were also interested in the situation of a specific category of patients - children. The most recent data in 2018 represents an incidence of 5.18 and 281 TB cases were reported. This represents a decrease of 96.4% compared to the year when report of TB started in Slovakia.

In the first forecast, we can observe a continuing downward trend in TB incidence. We also saw that the incidence threshold of 5.0 we set will be reached in 2022. Our findings indicated for that year an incidence rate of 4, 91 per 100 000 inhabitants. This consists of 265.33 patients. In 2038, we can even get under 2 sick patients per 100 000 inhabitants. The number of TB patients in a given year will be 106, 88 patients.

In the second prediction, we were interested in a specific category of patients, children. We have data on children in four age groups: 0 - 4, 5 - 9, 10 - 14 and 15 - 19-yr-old.

Donald (11) reports that, given the difficulties in diagnosing TB in children, there is significant evidence of an increase in the incidence of TB, which could contribute to the overall spread of TB worldwide. Some estimates indicate a 10% share of pediatric TB in total TB in the world. Available data linking the incidence of TB to the overall proportion of the disease suggests a sharp increase in cases caused by children, so that children can account for almost 40% of cases in some of the high-risk communities. In the developing world, pediatric TB is not controlled, even though the disease is a major health problem. Marušáková et al (12) by modeling predicted possible changes in the incidence of active pulmonary TB in children after abolition of BCG blanket vaccination in Slovakia. This model analyzed two scenarios for children aged 0-14 yr over a period of 15 yr. The results showed that the cost of preventing one case of active TB in children 0-14 yr old would be 784, 30 € lower when using newborn mass vaccination than in non-vaccination. The number of active TB cases would remain stable with a gradually decreasing trend if vaccination continues. If mandatory vaccination is abolished, the number of active TB cases could be up to five times higher in the model cohort.

TB infection remains an important cause of global morbidity and mortality. The burden of disease is greatest in developing countries around the world, although we also see an increase in morbidity in countries with a low TB incidence due to population migration. In countries with low TB incidence, there is a direct link between the globalization of health factors related to international population movements, as observed for TB and immigration policy in practice. Continued migration from areas with a high endemic TB will increasingly affect the health in low-incidence areas and challenge local controls and TB elimination programs. Reviewing time changes and TB predictions can play an important role in presenting health issues in the future, such as developing and disseminating control and intervention programs.

Conclusion

Treatment of TB should not be limited to the clinical and pharmacological demands; therefore, care should not be limited to the biological aspect. Instead, a comprehensive social and cultural focus is needed. Despite the low incidence and high percentage of treatment success rates of TB patients in Slovakia, this disease represents a significant problem especially in people who come from a socially weak environment. Identifying social determinants and identifying proper community interventions is a key role for healthcare professionals, which can lead to patient collaboration and successful management of the entire TB treatment course.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare that there is no conflict of interests.

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