Piotr Czupryna[1], Anna Moniuszko[1], Sławomir Pancewicz[1], Olga Zajkowska[2], Adam Garkowski[1], Sambor Grygorczuk[1], Maciej Kondrusik,[1] Joanna Zajkowska[1]

INFLUENCE OF CLIMATIC, DEMOGRAPHIC AND SOCIOECONOMIC FACTORS ON TICK-BORNE ENCEPHALITIS INCIDENCE IN 6 COUNTIES OF PODLASKIE REGION IN 1994-2014

[1]Medical University of Białystok, Department of Infectious Diseases and Neuroinfections
[2]Warsaw University of Life Sciences, Faculty of Applied Informatics and Mathematics

ABSTRACT

OBJECTIVES. The aim of the study was the analysis of possible influence of meteorologic, socioeconomic factors and land cover changes on tick borne encephalitis (TBE) incidence in Podlaskie region. We analyzed data from 6 counties in Podlaskie region (białostocki, suwalski, hajnowski, grajewski, kolneński, siemiatycki) from years 1994-2014.

MATERIALS AND METHODS. The analyzed data included: mean, minimal, maximal air temperatures (measured at 2 m above ground level), temperature amplitudes, rainfall, number of days with snowfall and duration of snow cover presence, population of each county, number of people employed as foresters, hunters, farmers and unemployed, area of each county, forests and agricultural area.

RESULTS. The statistical analysis showed correlations between TBE incidence and mean air temperatures in April and July. Moreover we stated correlation between TBE incidence and precipitation in April. TBE incidence was significantly higher in counties with high percentage of forested area. No significant correlations between TBE incidence and socioeconomic factors and land cover changes were observed.

Key words: *TBE, incidence, climatic factors, socioeconomic factors, Podlaskie region*

INTRODUCTION

Ticks are one of the biggest groups of vectors of diseases. They may transmit many pathogens e.g. tick borne encephalitis virus (TBEV), *Borrelia burgdorferi*, *Babesia*, *Anaplasma* (1).

Tick borne encephalitis (TBE) is considered as a marker disease for epidemiologic analysis of tick borne diseases. All hospitalized patients with TBE are reported to the Regional Epidemiologic Station. Additionally in most cases of TBE the approximate time of virus transmission is possible to determine as the disease develops in 1 month time since tick bite (2).

In Poland, the Podlaskie region is an endemic region for tick-borne diseases. Cases of TBE reported in the Bialostockie/Podlaskie region (before and after reorganization in administration and land division in 1998) constituted 43% and 46% of all cases reported in Poland, respectively (3). The research conducted in this area showed a significant increase in the incidence of TBE during last 20 years (3). Similar changes in TBE epidemiology were observed in other European countries (4, 5, 6).

Many theories were proposed for the explanation of this phenomenon. Some of them consider climatic changes and temperature rise the main factor that influenced on tick life cycle and lead to increase in the amount of TBE vectors. Other authors underline the meaning of socioeconomic and demographic changes which resulted in more frequent contacts with ticks (5-12).

AIM

The aim of the study was the analysis of possible correlation of meteorologic, socioeconomic factors and land cover changes on TBE incidence in Podlaskie region.

MATERIAL AND METHODS

We analyzed meteorological data from 6 counties in Podlaskie region (białostocki, suwalski, hajnowski, grajewski, kolneński, siemiatycki) from years 1994-2014. The counties were chosen in dependence to average TBE incidence (białostocki, suwalski, hajnowski – with relatively high incidence and siemiatycki, kolnenski, grajewski – with relatively low incidence).

The epidemiological data concerning TBE incidence in Poland and in Podlaskie region were acquired from National Institute of Public Health.

TBE has been a notifiable disease since 1994, therefore exact incidence data from each county are available since that year.

Daily meteorological data were acquired from the Institute of Meteorology and Water Management and from Climatic Research Unit, Norwich. The analyzed meteorological data included: mean, minimal, maximal air temperatures (measured at 2 m above ground level), temperature amplitudes (difference between maximal and minimal temperatures), rainfall, number of days with snowfall and duration of snow cover presence in years 1994-2014.

The demographic, socioeconomic and land cover data were acquired from Central Statistical Office of Poland and regional Employment Agency in Białystok. The data concerned years 1994-2014 and included: population of each county, number of people employed as foresters, hunters, farmers and unemployed, area of each county, forests and agricultural area.

All of 90 patients hospitalized in years 2012-2013 at the Department of Infectious Diseases and Neuroinfections in Bialystok completed a survey. All patients were inhabitants of Podlaskie Voivoidship. The patients voluntarily agreed to participate in the study and gave written consent.

The questions concerned the circumstances of tick bite and the knowledge about anti TBE vaccine.

Statistical analysis

The statistical analysis of data from 6 counties was performed with GLS regression. Two possible statistical models explaining the connection between TBE incidence changes and climatic conditions in April and July were constructed.

Additionally separate analysis with OLS regression was performed for białostocki county. Spearman rang test was used to assess correlation between analyzed parameters. $P<0.05$ was considered statistically significant.

RESULTS

TBE epidemiology

Until 1992, 2–13 cases of TBE were reported annually in Podlaskie region (incidence rate ranged from 0.4 to 1.9/100 000) (Fig.1).

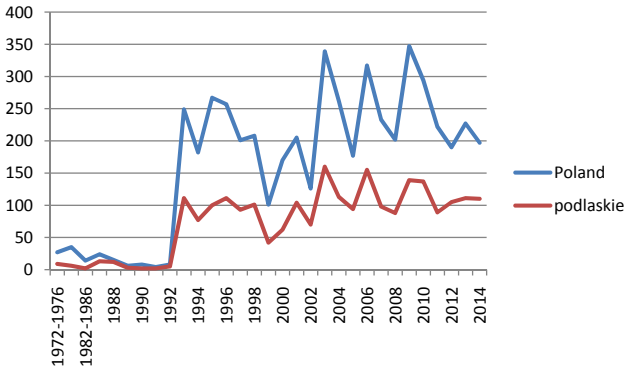

Fig.1 TBE incidence in Poland and in Białostockie/Podlaskie Region – years 1972-2014

In 1993 a significant increase in TBE incidence was observed (incidence rate 15.9/100 000). Since then the incidence rises gradually, with small peaks in 2003, 2006 and 2009.

Climatic data analysis

The analysis of mean temperatures in 3 time periods in 6 analyzed counties: 1994-2000, 2001-2007, 2008-2014 showed a steady increase in temperature: 7,3ºC±1,0, 7,4ºC±0,6, 7,5ºC±0,6.

The most significant changes were observed in mean, minimal and maximal temperatures in second and third dekad of April as well as in third dekad of October, second and third dekad of November.

The analysis of total annual rainfall during 3 periods of time shows a decrease: 1994-2000 – 584,2±54,3 mm, 2001-2007 – 561,0±67,5 mm, 2008-2014 – 619,9±109,0 mm.

In years 1994-2000 the mean number of days with snowfall was 46±9,8/year, in years 2000-2007 – 61,9±15,8/year and in years 2008-2014 – 62,4±16,1/year.

The statistical analysis showed negative correlations between TBE incidence and the number of days with snowfall ($R=-0.42$, $p<0.05$) in April.

Demographic and socioeconomic data analysis

The administration reform in 1998 caused no major changes in the borders of analyzed counties. In suwalski, hajnowski, grajewski, siemiatycki, kolnenski counties in years 1970-2014 a decrease in agricultural area was observed, while in bialostocki county there was an increase. In all counties an increase in forest area was observed.

These changes did not correlate with TBE incidence.

In all counties a significant reduction in the number of people employed as foresters, hunters and farmers was observed.

The number of unemployed inhabitants of Bialostockie Voivoidship in 1990 was 29262, while in 1998 (before administration reform) – 29703. After administration reform the number of unemployed in Podlaskie Voivoidship in 1998 was 62750, while in 2014 – 60394.

Survey results

Out of the 90 patients who completed the survey 60% were men. 34.5% of the patients were employed, 16.7% - unemployed, 39.9% - retired and 8.8% - students.

44 patients were bitten by tick during mushroom picking, 12 – during recreation, 13 – during work (forest workers, farmers), 21 – did not remember the tick bite.

48 patients were not vaccinated against TBE because they were unaware that a vaccine exists, 42 patients considered the risk of developing TBE as low. Only 8 patients stated that the vaccine was too expensive.

Statistical analysis

Identification strategy.

We assume possible two causalities binding weather and TBE incidence:

1) Weather is crucial for number of ticks in the analyzed area. We assume fraction of infected ticks is monotonic, increasing function of total number of ticks. The more infected ticks in the area the greater is the chance for the people to be bitten by infected tick. And therefore more registered TBE cases can be observed in the data. By weather in this channel we take meteorological conditions in April, when the thresholds of 5, 7 and 10ºC are reached.
2) Weather conditions can give incentives to visit areas with ticks for the people who otherwise would not go there. By weather in this channel we take meteorological conditions in July, when summer holiday in Poland start.

To analyze the influence of climate conditions on TBE incidence in the region, panel analysis was applied and models were estimated. Since we have obtained several potential explanatory variables and small number of degrees of freedom, we could not implement any standard variable selection algorithm. Therefore we have chosen variables to some extent arbitrarily on the basis of literature and our own experience. Additionally we were forced to test proposed causality channels separately.

Causality channel I

TBE incidence changes may be explained with meteorological conditions in April. After careful analysis we have chosen average temperatures and precipitations in all 3 decades of April. We have also included time

Table I. Influence of mean air temperatures and precipitation in April on TBE incidence in 6 counties in years 1994-2014. GLS regression

Incidence	Coef.	Std. Err.	P>|z|	[95% Conf. Interval]	
April 1st dekad mean temp	-0.3005	0.4503	0.504	-1.1830	0.5819
April 2nd dekad mean temp	-1.1342	0.5085	0.026	-2.1309	-0.1375
April 3rd dekad mean temp	0.6114	0.4479	0.172	-0.2665	1.4892
April 1st dekad precipitation	0.0571	0.0723	0.430	-0.0846	0.1988
April 2nd dekad precipitation	0.0237	0.0786	0.763	-0.1303	0.1778
April 3rd dekad precipitation	0.0420	0.1457	0.773	-0.2437	0.3276
const	-1.2557	6.5644	0.848	-14.1216	11.6102

Table II. Influence of mean air temperatures in July on TBE incidence in 6 counties in years 1994-2014. GLS regression

Incidence	Coef.	Std. Err.	P>|z|	[95% Conf. Interval]	
July 1st dekad mean temp	0.9857	0.4005	0.014	0.2008	1.7706
July 2nd dekad mean temp	-1.2451	0.5305	0.019	-2.2848	-0.2054
July 3rd dekad mean temp	1.3666	0.5489	0.013	0.2908	2.4424
const	-20.9074	9.1047	0.022	-38.7524	-3.0625

Table III. Influence of mean air temperatures and precipitation in second and third dekad of April on TBE incidence in białostocki county in years 1994-2014. OLS regression

Incidence	Coef.	Std. Err.	P>|t|	[95% Conf. Interval]	
April 2nd dekad mean temp	-1.6538	0.3384	0.001	-2.4194	-0.8883
April 3rd dekad mean temp	0.3022	0.3709	0.436	-0.5368	1.1412
April 2nd dekad precipitation	-0.0201	0.0532	0.714	-0.1404	0.1002
April 3rd dekad precipitation	-0.4119	0.1208	0.008	-0.6852	-0.1386
const	28.0293	5.4140	0.001	15.7819	40.2767

trend variable. Only average temperature in 2nd decade of April is statistically significant, we have decided to keep other variables in the model since they improve all R2 measures to greater extent that it would be possible by estimators' econometric properties. This model in 24.52% explains the variability in TBE incidence in examined counties. This model is presented in Table I.

Causality channel II

TBE incidence changes may be explained with meteorological conditions in July. All proposed variables are significant- time trend variable and average temperatures in all decades of July. Precipitation variables turned out to be insignificant and didn't improve explanatory properties of the model. Therefore they were exluded from the model. This model in 17.07% explains the variability in TBE incidence in examined counties. This model is presented in Table II.

Additionally we have decided to analyze separately bialostocki county, which is to some extend an outlier among analyzed areas. In this case OLS regression was used. Time trend is insignificant. Significant are estimates of average temperature in second decade of April and precipitation in third decade of April. Proposed variables explain 80,38% of TBE incidence variability in 1994-2014 period (Table III).

DISCUSSION

The analysis of changes in TBE epidemiology should include at least 3 factors: the pathogen reservoir (mainly small mammals), the vector (ticks) and possibility of transmission of the pathogen to humans. Climate changes might influence on all of these factors.

I. ricinus ticks start feeding in spring when the air temperature exceeds specific value (7ºC for nymphs and 10ºC for larvae). Larvae and nymphs both feed on small mammals. If the air temperature exceeds 10ºC it is possible that they feed simultaneously on the same host (co-feeding) and the virus may be transmitted between them. It results in increased number of infected ticks (12). The impact of temperatures in 3rd dekad of April and co-feeding on TBE incidence in Baltic states was reported by *Randolph* and *Sumilo* (8,12,13).Also *Zajkowska* et al described a potential connection of this phenomenon with TBE incidence in bialostocki county (14).

In all statistical models based on our data TBE incidence had a positive correlation with mean air temperatures in third dekad of April and negative correlation with mean air temperatures in second dekad of April. In third dekad of April mean air temperatures begin to exceed 10°C therefore lower temperatures in the previous dekad may allow better synchronization of larvae and nymphs feeding.

Additionally we observed correlations between TBE incidence and mean air temperatures in July. This phenomenon is hard to explain only by tick biology. It might be a consequence of human activity (higher temperatures may promote mushroom picking and active recreation).

This is in accordance with *Jaenson* et al, who explained sudden rise of TBE incidence in Sweden in 2011 (15).

The temperatures in late autumn are important for the tick life cycle. Higher temperatures prolong the time of tick activity and allow the transformation from larvae to nymphs, which are more probable to survive winter. Therefore the rise of temperatures observed in October and November might also have impact on TBE incidence.

The influence of rainfall on TBE incidence is ambiguous. Ticks are very susceptible to desiccation, therefore heavy rainfall should increase number of ticks and make the feeding easier. However too high level of rainfall leads to increased tick mortality.

The statistical analysis of our data showed that rainfall in April was one of the main factors influencing on TBE incidence.

Snow cover protects ticks during winter as temperature of ground under snow is higher than air temperature. However persistence of snow cover during spring delays the start of tick's feeding.

In our study there was a negative correlation between snow cover duration in April and TBE incidence.

Many authors state that although climatic changes played role in changing TBE epidemiology the impact of socioeconomic changes were even greater. *Randolph* et al. and *Sumilo* et al. reported that post-communist social transition in Baltic states increased human exposure to ticks (9,10,16).

Although the social transition in Poland was similar to Baltic States we did not observe significant changes in agricultural land area during the last dekads, however there was a slight increase in forested terrain area.

We observed decrease in employment in professions associated with elevated risk of exposure to tick bites: forest workers, farmers, hunters. It did not correlate though with TBE incidence.

Godfrey and Randolph analyzed the potential causes of TBE incidence rise in 2009. The authors analyzed the situation in Lithuania, Latvia and Poland and excluded possibility of climate influence on TBE incidence in this year. The authors state that the peak of incidence was associated mostly with human activities (mushroom picking) and low vaccination rate (17).

The results of the survey show that almost half of the patients were bitten by ticks during mushroom picking and 39.9% of patients were retired.

Barszcz et al reported in 2004 that income from the sale of harvested non-wood products amounted to about 27% in summer season and nearly 18% per year of the total income of poor families (18). According to the data from Central Statistical Office of Poland in 2014 the population at the post-productive age accounted of 18.7% of general population.

If we compare it to the results of our survey, it indicates that these groups are at risk of TBE infection.

Additionally the results of our survey indicate that the knowledge about TBE and vaccinations against TBE in Podlaskie region is very low. Most of the TBE patients who completed the survey did not vaccinate because they lacked knowledge of the risk of TBE and possibility of vaccination.

CONCLUSIONS

The rise of TBE incidence in Poland is a consequence of many factors either climatic or socioeconomic. However it seems that unlike e.g .in Baltic States, in Poland climate changes were more important for TBE epidemiology than socioeconomic changes.

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Address for correspondence:
Piotr Czupryna
Department of Infectious Diseases
and Neuroinfections
Medical University of Białystok, Poland
15-540 Białystok, 14 Żurawia Street
Tel. +48 85 7409514
e-mail: avalon-5@wp.pl

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