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ORIGINAL ARTICLE

Surveillance and epidemiology of Lyme borreliosis in the Czech Republic in 2018 and 2019

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Abstract

Lyme borreliosis (LB), the most prevalent vector-borne disease in Europe, is caused by *Borrelia burgdorferi* sensu lato complex species and transmitted by the tick *Ixodes ricinus*. The Czech Republic is an endemic country for LB. The disease affects the skin, neurological, musculoskeletal, cardiac or ocular tissue, and the most frequent clinical manifestations are erythema migrans and Lyme neuroborreliosis. In 2018, the EU case definition of Lyme neuroborreliosis was published, and neuroborreliosis has become reportable to the European Surveillance System. In this paper, we describe the LB surveillance system and reporting of human cases in the Czech Republic. Epidemiological characteristics of Lyme borreliosis are presented for 2018 and 2019. Gaps in and limitations of the existing national LB surveillance system were identified with regard to the reporting of neuroborreliosis in accordance with the EU case definition. In the Czech Republic, LB surveillance is nationwide, comprehensive, and mandatory. Case based data on all clinical manifestations of incident LB are reported to the electronic Information System of Infectious Diseases (ISIN). In 2018 and 2019, 4724 and 4102 LB cases, i.e., 44.5 and 38.4 cases per 100,000 population, were reported to ISIN, respectively. Overall, 46.3 % of cases were male and 53.7 % were female. The highest morbidity was observed in adults 50–75 and children 5–9 years old. The most affected regions were Vysočina and Olomoucký. Nine districts recorded more than 100 cases per 100,000 population. Erythema migrans appeared in 3173 (67.2 %) and 2756 (67.2 %) patients in 2018 and 2019, respectively. In 2018, 596 (12.6 %) Lyme neuroborreliosis cases were diagnosed only on the basis of clinical manifestations while in 2019, a total of 567 (13.8 %) cases of neuroborreliosis fully meeting the EU case definition were reported. The Czech Republic is an endemic country for LB with some hotspots, similar to some central, northern and north-eastern European countries. To implement the EU neuroborreliosis surveillance in the Czech Republic, ISIN technical update, addition of required variables to it, preparation of legislation update, and training of health professionals were needed.

Keywords Lyme borreliosis · Surveillance · *Borrelia burgdorferi* sensu lato · Neuroborreliosis · *Ixodes ricinus* · Epidemiology

Introduction

Lyme borreliosis (LB) is the most prevalent and widespread vector-borne human infection in northern hemisphere and occurs across Europe and its geographical distribution is increasing (Rizzoli et al. 2011).

The Czech Republic is an endemic country for LB, between three to five thousand of autochthonous human cases have been reported annually. In the last decade, the incidence ranged from 27.6 to 46.1 cases per 100,000 population (Kříž et al. 2018). Temperate climate and biotopes with deciduous and miscellaneous vegetation are suitable for the life cycle of various reservoir animals and the vector tick *Ixodes ricinus* (Linnaeus, 1758), occurring across the country. The causal agents, the spirochaetes *Borrelia burgdorferi* sensu lato (s.l.), and genospecies *Borrelia afzelii, B. garinii, B.*

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burgdorferi sensu stricto (s.s.), *B. bavariensis, B. bissettii, B. valaisiana, B. spielmanii*, and *B. lusitaniae* were detected in ticks or animals in natural, semi-urban and urban areas of Czechia (Venclíková et al. 2014; Hönig et al. 2015; Kybicová et al. 2017). All of the fourteen administrative regions of the Czech Republic have been affected, and the risk areas are expanding to higher altitudes (Daniel et al. 2009, 2016; Danielová et al. 2010).

LB diagnosis is based on clinical symptoms, epidemiological circumstances, exposure, and laboratory tests. Clinical manifestation of LB in the early to late stages of infection is localised or disseminated. Among the skin lesions in the early phase, erythema migrans is the most frequent symptom, less common is borrelial lymfocytoma, and in the late phase, acrodermatitis chronica atrophicans occurs. Neurological conditions are meningoradiculoneuritis, meningitis, meningoencephalitis, encephalomyelitis, radiculomyelitis, neuritis, and neuropathy. Further manifestations are musculoskeletal, mainly arthritis, cardiac, and ocular (Stanek et al. 2012; Krbková et al. 2018).

LB is believed to be the vector-borne disease with the highest burden in Europe (Semenza and Zeller 2014). However, the surveillance of LB, public health strategies, and health policy vary among the EU Member States. Moreover, there are different diagnostic approaches, epidemiological data gathering focus on diverse indicators, and reporting covers various administrative units (Van den Wijngaard et al. 2017). Consequently, the outcomes are hardly comparable between countries, and the assessment of LB burden has limitations. The need for integrated surveillance in the prevention and control of emerging vector-borne diseases including LB was expressed by public health experts, the European institutions, and patient organisations. Neuroborreliosis seemed most feasible and useful as the standard key indicator (Van den Wijngaard et al. 2017).

In 2018, the EU-wide surveillance of Lyme neuroborreliosis was introduced (Hy and Muhhamad 2018), and the new EU case definition was published (European Commission 2018).

We attempted to find out whether the current national surveillance system in the Czech Republic is ready for the new requirements of the European LB surveillance. We described the epidemiological characteristics of LB in the Czech Republic in 2018 and 2019. Finally, we identified the needs of and changes to be made to the Czech surveillance system in response to the new requirements for notification of Lyme neuroborreliosis to the European surveillance system (TESSy).

Materials and methods

We described the surveillance system of human LB in the Czech Republic in the context of the public health system.

We analysed data on individual LB cases reported to the surveillance system in 2018 and 2019. The epidemiological characteristics of LB were linked to person, place, and time. Data on morbidity were presented as the absolute numbers of cases and relative incidence rates per 100,000 population. The source of the case-based LB data was the national electronic reporting system called the Information System of Infectious Diseases (ISIN), to which the newly diagnosed LB cases with all clinical manifestations are reported. Anonymized data were used for analysis. The data on population were obtained from the Czech Statistical Office.

Categorical data are presented in the form of absolute frequencies and percentages, and continuous data using means. Statistical analysis was based on the chi-square test and analysis of variance. Results with a p-value less than 0.05 were considered statistically significant. Data analysis was performed using MS Excel and statistical software Stata, release 14.2 (Stata Corp LP, College Station, TX, USA).

Results

Surveillance of human Lyme borreliosis in the Czech Republic

Reporting systems historically and currently

In former Czechoslovakia, the first human LB cases were reported in the mid-1980 s, when the routine laboratory diagnostics of borreliae in human samples became available. Infectious diseases were originally reported through the Information System of Communicable Diseases (ISPO). Later, the EPIDAT system was developed to ensure mandatory reporting, registration, and analysis of infections. After the country split, in the Czech Republic, the electronic EPIDAT system was used nationwide by all public health authorities as a basis for local, regional, and national surveillance of infectious diseases between 1993 and 2017.

Since 2018, a new reporting system ISIN has been introduced. The ISIN is owned by the Ministry of Health of the Czech Republic and managed and technically operated under the Institute of Health Information and Statistics of the Czech Republic (ÚZIS). The ISIN has still been evolving. The Department of Biostatistics and the Department of Infectious Diseases Epidemiology of the National Institute of Public Health were and have been significantly involved in the development and operation of both the EPIDAT and ISIN. The ISIN advisory group is composed of field and national epidemiologists, biostatisticians, laboratory specialists, and IT experts.

Characteristics of surveillance notification of human LB cases

In the Czech Republic, the surveillance of human LB cases is comprehensive, nationwide, and covers the whole population. Data are obtained from all 14 administrative regions of the

Czech Republic through the respective Regional Public Health Authorities. Lyme borreliosis is a mandatory notifiable disease in the Czech Republic. The obligation of reporting is stipulated by law.

Case definition

All clinical forms of LB are reported within the surveillance programme, with the ICD-10 code A69.2. The national case definition includes clinical, laboratory, and epidemiological criteria.

The clinical criteria encompass any clinical manifestation of LB: early stage, localised erythema migrans, early disseminated presentations like skin lesions (borrelial lymphocytoma), musculoskeletal, neural, and cardiac manifestations (myalgia, arthralgia, recurrent arthritis, cranial neuritis, meningoradiculoneuritis, Garin-Bujadoux-Bannwarth syndrome, aseptic meningitis, carditis, etc.). Late manifestations occur months to years after infection as affections of the nervous system (chronic encephalopathy, polyneuritis, depression, or other psychiatric manifestations), joint problems (Lyme arthritis), and skin lesions (inflammatory or atrophic acrodermatitis).

The epidemiological criteria should be met for at least one of the following epidemiological links in the period of four weeks before onset of symptoms: confirmed tick bite; stay in an area with the occurrence of ticks; unsafe practices when handling a tick, especially during tick removal when there was a direct contact with the patient's skin.

Laboratory diagnosis is needed for all clinical forms except erythema migrans. The two-steps serological tests (ELISA and consequently Western blot) are predominantly used for detecting anti-*Borrelia* IgM and IgG antibodies in serum, cerebrospinal fluid, or synovial fluid. Culture of *B. burgdorferi* s.l. or direct detection of the *Borrelia* antigen or DNA, possibly supported by microscopy are also considered as fulfilling the laboratory criteria.

Case classification: a possible case meets the clinical criteria; a probable case fulfils the clinical and epidemiological criteria; a confirmed case is a laboratory confirmed case with clinical manifestation.

Detection of cases, data flow and institutions/ professionals involved in reporting

Detection of LB cases is performed by clinicians and laboratories. The general practitioners, hospital physicians, or outpatient specialists review the patient's symptoms and if relevant send the specimens from suspected cases to a laboratory. The diagnostic test can be performed in any laboratory involved in the External Quality Assessment (EQA). The diagnostic laboratory should notify the positive result to both the requesting medical doctor and the relevant Regional Public Health Authority in accordance with the residence place of the patient.

The National Reference Laboratory for Lyme Borreliosis (NRL), located at the National Institute of Public Health in Prague (NIPH), plays an important role in the surveillance. The NRL not only performs confirmation testing or the diagnostics for special cases but also provides the full panel of testing methods, including culture, electron microscopy, and molecular tests. The NRL organizes the EQA for all diagnostic laboratories in the Czech Republic and regularly participates in the international quality control scheme. The NRL has been involved in designing the surveillance strategy, preparation of guidelines, research, and detection of Borrelia in ticks.

Figure 1 shows the structure of the reporting system. General practitioners for adults, pediatrists, hospital physicians, and outpatient specialists, mainly infectologists, neurologists, and dermatologists report individual LB cases to the respective district branches of the Regional Public Health Authority (RPHA). Field epidemiologists, who are employees of the RPHA, compile data about each case. Information obtained directly from patients, laboratory results, and medical records are put together with general data, clinical symptoms, epidemiological circumstances, and possible exposure. The comprehensive case-based data are entered into the electronic reporting system ISIN. The system is accessible only for designated professionals depending on their role in the system, work position and administrative level. Accordingly, the Regional Public Health Authorities are responsible for data entry from their respective administrative units. The National Institute of Public Health (the Department of Biostatistics in cooperation with the Department of Infectious Diseases Epidemiology) ensures the reporting of national data to the TESSy. Data on LB are analysed by epidemiologists and biostatisticians and published in journals or on the website.

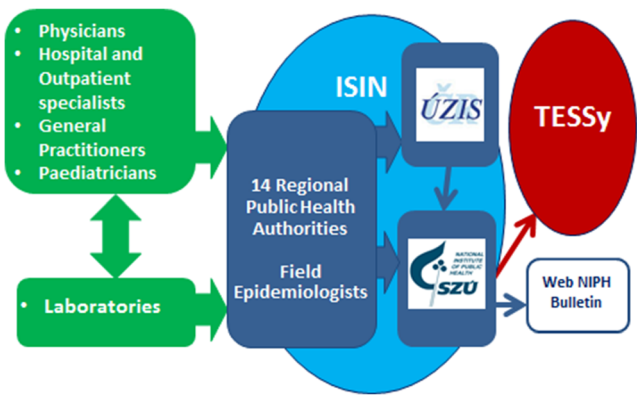

Fig. 1 Structure of the reporting system of infectious diseases, Czech Republic

National legislation, preventive program and guidelines

The surveillance of LB in the Czech Republic is embedded in legislation. The implementing regulation of Act No. 258/2000 on the protection of public health and on amendments to some related acts, is Ministerial Regulation No. 473/2008 of 17 December 2008 on the system of epidemiological vigilance for selected infections, as amended by Regulations Nos. 275/2010 and 233/2011, whose Appendix No. 23 describes the system of epidemiological vigilance of Lyme borreliosis.

Appendix No. 23 defines the clinical, epidemiological, and laboratory criteria for the case classification of Lyme borreliosis. Furthermore, the Regulation specifies data gathering and mandatory reporting, epidemiological investigation of LB cases, and control measures against the spread of LB.

Regulation No. 473/2008 also indicates the preventive program aimed at informing citizens and protecting them against tick infestation. A prediction program called TickPro (Daniel et al. 2010) was created in cooperation with experts from the National Institute of Public Health and Czech Hydrometeorological Institute. The TickPro forecast is based on mathematical models utilizing the correlation of meteorological data (air temperature, quantity of atmospheric precipitation and relative air humidity) with the host-seeking activity of *I. ricinus*. During the season from March to November, the level of tick activity measured on a ten-point scale is presented on the websites of the relevant authorities. The risk of infection increases with increasing tick activity. Every risk level is accompanied by recommendations on the preventive measures, i.e., on how to behave and what specific safety measures to follow in order to minimize the risk of tick-borne diseases.

On 30 September 2018, the Society of Infectious Medicine of the J. E. Purkyně Czech Medical Association issued the "Guidelines on the Diagnosis and Treatment of Lyme Borreliosis" (Krbková et al. 2018). The purpose of these Guidelines is to draw attention to the clinical manifestations of LB infection, to summarize the diagnostic algorithm, and to recommend the appropriate antibiotic treatment. They are intended for physicians, general practitioners, and health care specialists and were developed based on long-term clinical experience of the authors and in compliance with the recommendations of some other European countries and evidence-based medicine.

Epidemiology of Lyme borreliosis in the Czech Republic in 2018 and 2019

The epidemiological data showed an overall increasing trend in LB incidence from the beginning of reporting to the present (Fig. 2). The numbers of reported LB cases were rising from the late 1980 s to 1995, which was followed by three years of decrease before the end of the 20th century. For the recent two decades, the tendency was stable with the annual incidence ranging from 27.6 to 46.1 cases per 100,000 population.

In the Czech Republic, a total of 8,826 LB cases were reported to the national reporting system ISIN in the recent two-year period: 4724 and 4102 cases in 2018 and 2019, respectively. The respective overall incidence rates were 44.5 and 38.4 per 100,000 population, 47.7 and 40.1 in females and 41.1 and 36.8 in males per 100,000 population.

In 2018 and 2019, 2152 and 1934 cases were reported in males and 2572 and 2168 cases in females, respectively. The female to male ratios were 1.19 in 2018 and 1.12 in 2019. Gender representation did not differ essentially ($p = 0.134$) between the two study years. Overall, the share of men was 46.3 % and that of women was 53.7 %.

In 2018, the mean age of the patients was 45.5 years, median 50. In 2019, the mean age was 44.7, median 49. There was a statistically significant ($p < 0.001$) difference in the mean age between males (43.0; 41.5) and females (47.7; 47.5) in both years; however, there was no significant difference between the two years ($p = 0.104$).

Table 1 shows the totals of cases broken down by sex and age group for 2018 and 2019. The gender representation in age groups differs slightly between the two years ($p = 0.038$). The proportion of cases in particular age groups does not differ significantly between years ($p = 0.095$). The most affected was the age group 60–69 years, with 1742 LB cases, i.e., 19.74 % of all 8,826 cases reported during the two years. In both years, the highest morbidity of over 50 cases per 100,000 population occurred in the adult age group 50–75 years and children 5–9 years old (Fig. 3).

LB cases were notified from all administrative units, with the reported incidence in the fourteen administrative regions ranging from 17.9 to 118.5 per 100,000 population in 2018 and from 13.2 to 101.1 per 100,000 population in 2019 (Table 2). There were significant differences ($p < 0.001$) in the regional distribution between the two years. By place of residence, the most affected regions were Vysočina, Olomoucký, and Zlínský. Among 77 administrative districts of the Czech Republic, nine reported more than 100 cases per 100,000 population in at least one of the two years. Figure 4a and b show the annual incidence per 100,000 population by district in 2018 and 2019. The highest annual incidence was reported in the following districts: Třebíč (190 cases per 100,000 population in 2018), Český Krumlov (147/100,000 in 2018), Vsetín (140/100,000 in 2018), Přerov (138/100,000 in 2018), Semily (134/100,000 in 2019), Žďár nad Sázavou (129/100,000 in 2019), Rokycany (121/100,000 in 2018), Šumperk (120/100,000 in 2018), and Jihlava (115/100,000 in 2018).

Seasonal occurrence from April to November in both years was characterised by a sharp rise in May, more pronounced in 2018 when it was even twice as high in comparison with the previous years, with the curve following the upper limit for the

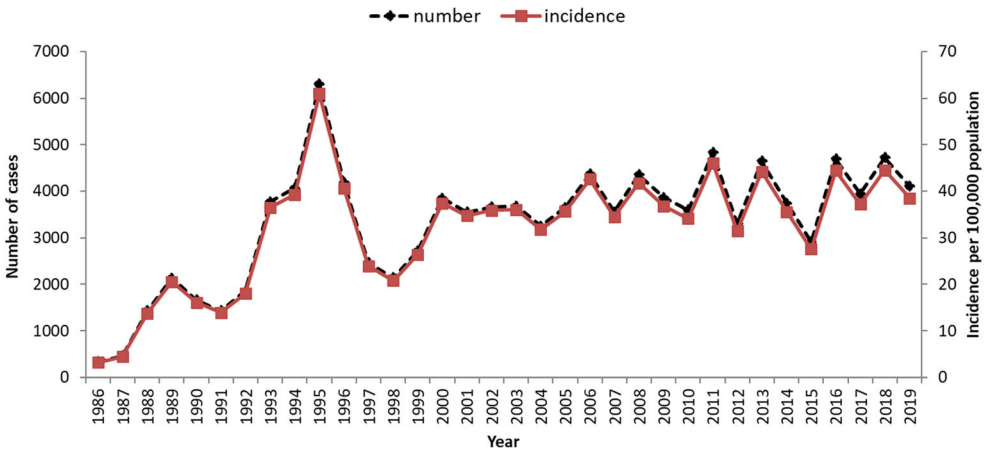

Fig. 2 Lyme borreliosis, Czech Republic, 1986-2019, number of cases and incidence per 100,000 population. Source: ISPO, EPIDAT, ISIN

previous years. Spring to autumn distribution showed two peaks in June and July in 2018 and one peak in June to mid-July in 2019 which was lower than those in 2018. The August incidence reached 70 %, and 80 % of the July figures, respectively.

In both seasons, almost 60 % of patients experienced either a tick bite (5146; 58.3 %) or had a direct contact with a tick when handling it during removal (25; 0.3 %) while for 3655 (41.4 %), the exposure was unknown or not completed. Differences in exposure between both years were not statistically significant ($p = 0.155$).

Table 1 Lyme borreliosis by gender and age group, Czech Republic, year 2018 and 2019, number of cases

	Year 2018			Year 2019		
Age group	Male	Female	Total	Male	Female	Total
0–4	89	110	199	103	87	190
5–9	218	176	394	163	154	317
10–14	98	87	185	125	81	206
15–19	62	60	122	67	73	140
20–24	56	43	99	57	39	96
25–29	91	80	171	78	46	124
30–34	110	87	197	87	86	173
35–39	121	130	251	109	114	223
40–44	174	210	384	194	132	326
45–49	169	190	359	143	137	280
50–54	167	201	368	136	197	333
55–59	146	218	364	156	207	363
60–64	187	286	473	158	233	391
65–69	214	271	485	164	229	393
70–74	141	240	381	111	201	312
75–79	82	116	198	56	98	154
80–84	20	46	66	19	37	56
85+	7	21	28	8	17	25
total	2152	2572	4724	1934	2168	4102

More than 20 % of all 8826 LB cases required hospitalization in the two-year period, with 1428 (16 %) patients being admitted to the infectious diseases wards, 467 (5 %) to other hospital wards, and 12 persons to some other facility. A total of 2536 (29 %) persons were treated on an outpatient basis, and for 4383 patients (50 %), the information about the place of treatment was not available. Differences in the distribution of places of treatment between the two years, 2018 and 2019, are not statistically significant ($p = 0.416$).

Clinical manifestation was assessed based on clinical symptoms reported to ISIN. In both years, the most frequent symptom was erythema migrans, reported in 3173 (67.2 %) and 2756 (67.2 %) patients, respectively. Based on clinical manifestations, Lyme neuroborreliosis was recorded in 596 (12.6 %) cases in 2018. In 2019, a total of 567 (13.8 %) Lyme neuroborreliosis cases were identified in the national database ISIN to comply with the EU case definition for neuroborreliosis and were reported to TESSy.

Discussion

During the four decades of LB surveillance in the Czech Republic, the reporting of human LB cases was able to monitor the disease incidence and trend. A high LB incidence, between 30 and 50 cases per 100,000 population, i.e. three to five thousand new LB cases annually, signify a major burden of LB for the population and health system. The Czech Republic is a country with a high LB incidence unlike Western European countries where LB is estimated to be less common (Sykes and Makiello 2016; Cairns et al. 2019). On the other hand, hotspots with more than 100 cases per 100,000 population were recorded in parts of Slovenia, Austria, Germany, southern Sweden, Baltic coastline in southern Sweden, some Finnish and Estonian islands (Rizzoli et al. 2011), and Lithuania (Petrulioniene et al. 2020).

In the Czech Republic, the surveillance reporting is nationwide, comprehensive, and mandatory. A certain level of

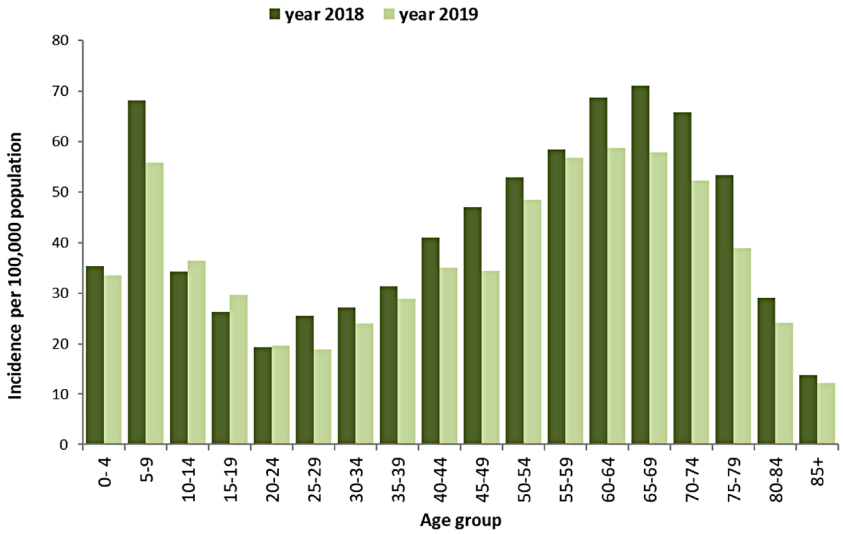

Fig. 3 Lyme borreliosis by age group, Czech Republic, 2018 and 2019, incidence per 100,000 population Source: ISIN

underreporting can be caused by the fact that the system relies on passive reporting. However, the assessment of underreporting was not performed.

The analysis of case-based data on incident LB cases reported to the new electronic notification system ISIN in 2018 allowed to summarize basic demographics of patients such as age and sex; time of onset and notification; pathogen isolation; information about place of residence, exposure, clinical manifestation, and laboratory diagnosis (Orlikova et al. 2019). The epidemiological characteristics of Czech human cases, i.e., age, sex ratio, proportion of erythema migrans among cases and observed tick bites, were comparable with those in a Lithuanian study (Petrulioniene et al. 2020).

Table 2 Lyme borreliosis by administrative region of reporting, Czech Republic, years 2018 and 2019, incidence per 100,000 population

Region of reporting	Year 2018	Year 2019
Praha	17.9	13.2
Středočeský	31.6	24.3
Jihočeský	73.9	67.3
Plzeňský	38.2	25.5
Karlovarský	20.6	23.1
Ústecký	28.4	29.2
Liberecký	65.9	60.8
Královehradecký	47.5	61.5
Pardubický	39.5	45.0
Vysočina	118.5	101.1
Jihomoravský	25.7	22.5
Olomoucký	92.7	69.6
Zlínský	78.4	58.5
Moravskoslezský	30.4	25.3
Czech Republic	44.5	38.5

Source: ISIN

We have described the clinical manifestation of cases using the ISIN categorical variable called "clinical symptoms". Some symptoms are nonspecific and thus can appear in different clinical forms of the disease. Therefore, for some cases, it was not possible to clearly specify the clinical form. For patients with Lyme neuroborreliosis, a piece of information was missing to align with the EU case definition of neuroborreliosis. The estimate of 596 (13 %) clinical neuroborreliosis cases in 2018, identified solely on the basis of clinical symptoms, can be somewhat lower than the real number of cases. Moreover, some additional variables, both laboratory and clinical, described in the EU case definition for neuroborreliosis, were not available in the national notification system ISIN in 2018. Therefore, data on Lyme neuroborreliosis from 2018 were not reported to the European surveillance reporting system TESSy. Only ten countries provided to TESSy data on a total of 592 Lyme neuroborreliosis cases newly diagnosed in 2018.

Currently, the Czech Republic is in a transition period regarding the adoption of the EU neuroborreliosis case definition. The implementation started with adding new variables to the national system ISIN during the year 2019. The variables in ISIN have to correspond with the TESSy Metadataset variables and the ECDC Reporting Protocol for neuroborreliosis. The ISIN has proved sufficient flexibility; however, it took certain time to make the technical changes. Among others, the action taken was discussed in advance with ISIN advisory group members, representatives of the field epidemiologists, biostatisticians, epidemiologists, and laboratory experts at the NIPH. Technically, electronic ISIN updates were performed by the ÚZIS experts, who are responsible for technical changes to the system. Still, there is a need to evaluate the new reporting for acceptability and data quality after the implementation of the last changes during the year 2019. A total of 567 neuroborreliosis cases notified to the Czech national

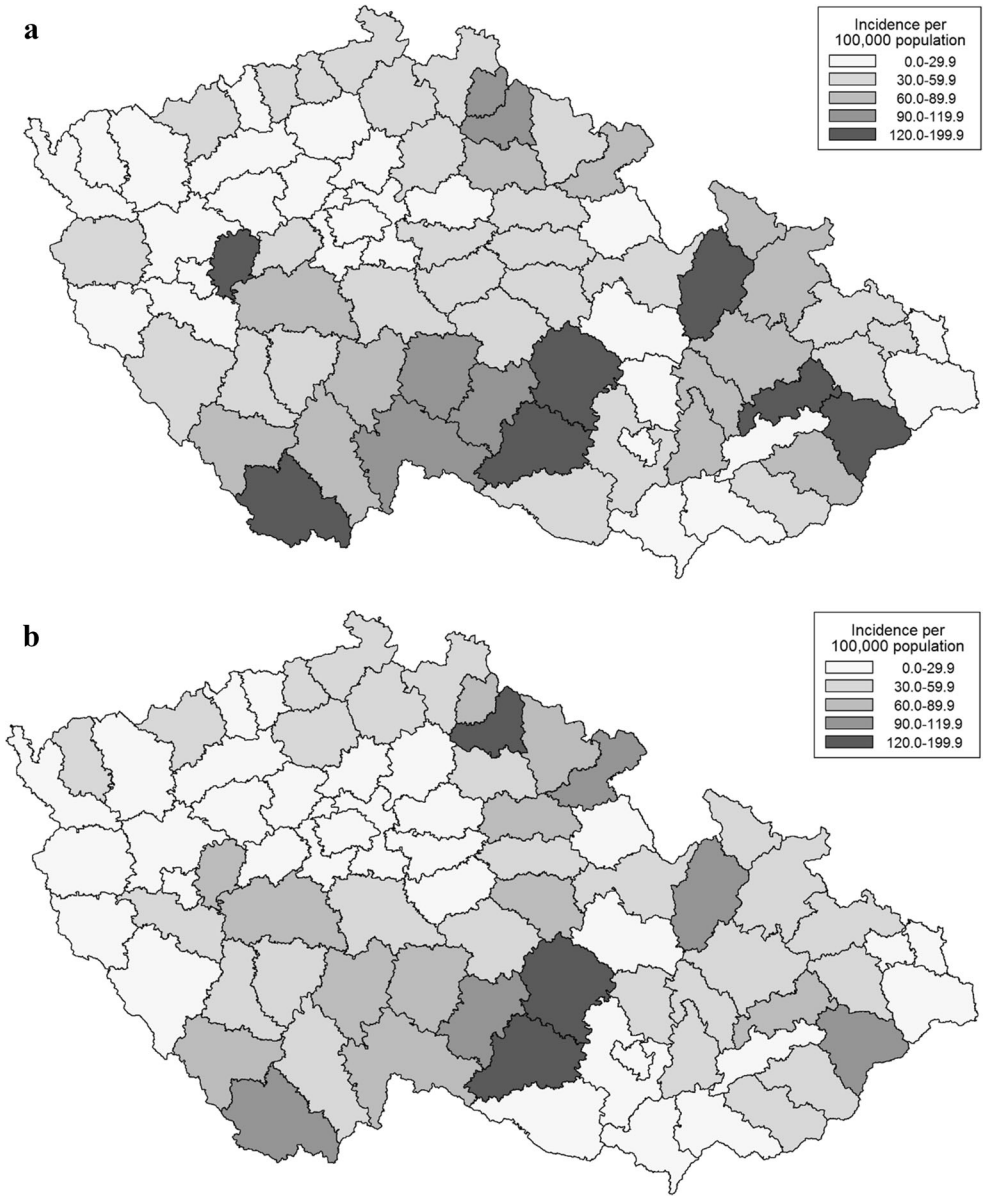

Fig. 4 **a** Lyme borreliosis by administrative district of reporting, Czech Republic, incidence per 100,000 population, 2018; **b** Lyme borreliosis by administrative district of reporting, Czech Republic, incidence per 100,000 population, 2019. Source: ISIN

surveillance system in 2019 were reported to TESSy, which represents 35.66 % of all neuroborreliosis cases diagnosed in 14 European countries. To maintain continuity of the surveillance outcomes in the Czech Republic, the country-wide reporting of all LB clinical manifestations is required without changes.

LB surveillance is challenging, and surveillance performance differs between countries. Even in two neighbouring states, the epidemiological situation can vary essentially when comparing outcomes using the surveillance data from the bordering districts (Stefanoff et al. 2014). Several surveillance strategies for LB surveillance are utilised in EU/EEA countries based on various key indicators: erythema migrans, neuroborreliosis, all human LB manifestations, seroprevalence, tick bites, and infected ticks and reservoir hosts (Van den Wijngaard et al. 2017). Data are obtained from primary care, hospitals, laboratories, or other sources.

Seroepidemiological studies have been conducted in various European countries. The seroprevalence varies considerably in different countries, with overall increasing prevalence from west to east in central and eastern Europe and decreasing incidence in Greece, Spain, and from north to south in Italy (Santino et al. 2006),

The key indicator incidence of new LB cases is obtained using different methods. A review and surveillance reports in 17 Western European countries estimated the unweighted mean incidence of LB to be 56.3/100,000 per year and the population-weighted incidence of LB in Western Europe to be 22.04/100,000 person-years (Sykes and Makiello 2016).

The incidence of Lyme disease in some countries has increased as was documented in a large population-based cohort study in the UK using data from the general practitioners database. The incidence in the UK increased rapidly over the years 2001 to 2012 to an estimated incidence rate of 12.1 (95 % CI 11.1 to 13.2) per 100,000 population (Cairns et al. 2019). In Lithuania, a highly endemic country, the average annual crude incidence rate was 85.4 cases per 100,000 population in the period 2014–2016 and the data for retrospective analysis were collected from the Centre for Communicable Diseases and AIDS of Lithuania (Petrulioniene et al. 2020).

In order to consolidate and coordinate the European surveillance, Decision 1082/2013/EU (European Parliament and Council of the European Union 2013) has promoted and strengthened the preparedness coordination between the EU Member States. Regarding LB there was a need for further actions to bring the coordination and network for the epidemiological surveillance to a higher level. Several years lasting debate concerning the best solution for LB European surveillance resulted in the obligation for the Member States to report neuroborreliosis. Despite the fact that Lyme neuroborreliosis was not a notifiable disease in all European countries, the EU-wide surveillance of Lyme neuroborreliosis was introduced.

The new EU case definition for Lyme neuroborreliosis was declared by Commission Implementing Decision (EU) 2018/945 (European Commission 2018). Further initiative to support and underline LB importance of in the European region was the European Parliament resolution of 15 November 2018 on Lyme disease (Borreliosis) (2018/2774(RSP)).

The current surveillance of LB human cases in the Czech Republic is specified in legislation. The next step will be the implementation of the EU Lyme neuroborreliosis case definition in the national legislation, Ministerial Regulation No. 473/2008.

An evaluation of surveillance performance attributes of data quality, feasibility, and acceptability will be desirable after the addition of the new elements to the reporting system.

Since there is no specific vaccine available to prevent LB, early detection and reliable diagnosis are crucial for providing timely treatment. The country-wide coverage by laboratories enables access to laboratory diagnosis of LB. The Czech Republic is an endemic area for Lyme borreliosis, and it is important to raise awareness of health professionals. The national guidelines from 2018 (Krbková et al. 2018) facilitate the procedures for evidence-based diagnosis and treatment. LB control strategies require multidisciplinary involvement (Sprong et al. 2018).

Comprehensive surveillance of LB comprises not only diagnosis, treatment, and reporting of human LB cases but also other indicators. An important part is the monitoring of the vector *I. ricinus*, pathogenic species from the *B. burgdorferi* s.l. complex, and reservoir animals, along with the influencing factors like weather, climate, and environmental changes. Long lasting cooperation between the National Institute of Public Health and the Czech Hydrometeorological Institute has resulted in a useful predictive model of tick activity (Daniel et al. 2010). Transformation of the public health authorities and state administration in the beginning of the 21st century led to a reduction of workforce capacity, and that is why not all Regional Public Health Authorities manage to monitor tick abundance. This monitoring is partially covered by field studies and projects of the National Institute of Public Health in Prague, Public Health Institute in Ostrava, Czech Academy of Sciences, and universities.

Conclusions

LB remains the most frequent vector-borne disease in the Czech Republic, with three to five thousand cases reported annually. It poses a large burden to the affected individuals and health system.

The nationwide, comprehensive, and mandatory surveillance reporting of Lyme borreliosis in the Czech Republic is able to provide sufficient outcomes to monitor disease trends and epidemiological characteristics.

In 2018 and 2019, totals of 4724 and 4102 LB cases were reported, i.e., 44.5 and 38.4 cases per 100,000 population, respectively. Higher morbidity was observed in females, older age groups and young children. The most affected regions were Vysočina and Olomoucký. The most frequent clinical manifestation was erythema migrans, found in two thirds of patients. Almost six hundred patients had clinical symptoms of neuroborreliosis, which represents 13 % of all cases. Nevertheless, this estimation has certain limitations due to some missing specific variables and the technical condition of ISIN.

In 2018, the Czech surveillance reporting was not able to provide complete information required for the European surveillance of Lyme neuroborreliosis and its notification to TESSy. Therefore, the Czech surveillance needed an update in order to report neuroborreliosis to TESSy. In 2019, the initial changes related to the Lyme neuroborreliosis reporting to TESSy were implemented and some new variables were added to the national electronic reporting system ISIN. The update of legislation is ongoing, and the case definition of Lyme neuroborreliosis will be added to the current national LB case definition.

Nevertheless, reporting of all clinical forms of LB will be retained in order to continue the complex LB surveillance including monitoring of LB overall morbidity, epidemiological characteristics, geographical distribution, seasonal occurrence, and risk factors. A reliable surveillance system is an important prerequisite for monitoring the impact of LB in the Czech Republic.

Further action should focus on compliance with the amendments. An evaluation of surveillance performance attributes of data quality, feasibility and acceptability will be desirable after the addition of the new elements to the reporting system.

The training of health professionals, field epidemiologists, and public health staff who are involved in the reporting process has been a part of the implementation.

An interdisciplinary and interinstitutional collaboration is needed not only in the study of human LB but also in the monitoring of the vector *Ixodes ricinus* and reservoir animals and of the effect of climate and environmental changes.

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Conflict of interest The authors declare that they have no conflict of interest.

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