Veterinarski Glasnik 2019, 73 (2), 133-143
UDC: 636.4.09:616.995.132-036.2(497.11)"1994/2018"
616.995.132-036.2(497.11)"1994/2018"
https://doi.org/10.2298/VETGL191022024M

Full Research Article

DISTRIBUTION OF *TRICHINELLA* INFECTIONS IN PIGS AND TRICHINELLOSIS IN HUMANS IN SERBIA FROM 1994 TO 2018

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Received 22 October 2019; Accepted 16 November 2019
Published online: 21 November 2019

How to cite: Mirilović Milorad, Tajdić Nada, Vejnović Branislav, Đurić Spomenka, Mirilović Nikola, Maris Slavica, Šaponjić Vladan. Distribution of *Trichinella* infections in pigs and trichinellosis in humans in Serbia from 1994 to 2018. *Veterinarski Glasnik*, 2019. 73 (2), 133-143. https://doi.org/10.2298/VETGL191022024M

Abstract

Introduction. Trichinellosis is a disease in humans caused by parasites of the genus *Trichinella*, and these roundworms can occur in a variety of animals (over one hundred mammal species). Members of the genus *Trichinella* are present in almost all continents and in all climate zones. Intensive studies on the eradication of this disease have been going on for a long period, but despite the finances invested in research projects, trichinellosis is still present in the 21st century and poses a major health issue all over the world. According to current scientific estimations, there are over 27 million *Trichinella*-infected people in the world. The aim of our study was to determine the distribution and trends for *Trichinella* infection in pigs and trichinellosis in humans in Serbia between 1994 and 2018.

Materials and Methods. Data for the 25-year surveillance period of *Trichinella* cases registered in pigs and humans in Serbia was gathered from the Veterinary Directorate and from the Institute of Public Health of the Republic of Serbia. The data obtained was analysed with the relative numbers of structure and dynamics, indices and descriptive statistical indicators.

Results and Conclusions. During the research period, 14,837 pigs were diagnosed as infected with *Trichinella*. Out of this number, 87.31% of pigs were identified in the five

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epizootiological regions, and only 12.69% were diagnosed in the non-epizootiological regions in Serbia. During the period 1994-2018 in Serbia, a total of 6,850 people were treated for *Trichinella* infection. Out of this number, 4,153 (60.63%) people were from the five epizootiological regions. The trend-line describing the presence of *Trichinella* in pigs was defined by a fourth degree polynomial function. Meanwhile, the trend-line describing the presence of trichinellosis in humans was defined by a sixth degree polynomial function. Trichinellosis in Serbia is most common during the winter season, from December to March.

Key words: trichinellosis, pigs, trend, distribution

INTRODUCTION

Trichinellosis is a disease in people caused by roundworms from the genus *Trichinella*. In Serbia, *Trichinella* has been present in the domestic pig population for a long time. Over an observed period of 25 years, it was constantly present along the major river catchment areas in the country (Sava, Danube, Velika Morava, and Drina) (Sofranić et al., 1997). In the epizootiological Srem and Podunavsko-Braničevska regions, *Trichinella* is sporadic, especially along the left riverbank of the river Sava, and the right riverbank of the river Danube. In the last decade of the 20th century due to the proximity of the war zone, the economic crisis and political instability, there was an expansion of trichinellosis in humans and *Trichinella* in pigs (Teodorović et al., 1999). The closure of large pig farms and poor veterinary and sanitation measures resulted in the free spread of the parasite. Other factors such as inadequate pig feeding protocols, extensive pig breeding and the lack of financial competition in the pig industry resulted in large numbers of infected pigs. This expansion of *Trichinella* infections reached alarming proportions.

The aims of this study were to determine the distribution of *Trichinella* infections in pigs and trichinellosis in humans in five epizootiological regions in Serbia over a 25-year period and to establish trends for *Trichinella* infections in pigs and humans. For this research we utilized the local administrative setup, and the organization of municipalities into epizootiological regions in which all veterinary health measures are carried out by veterinary clinicians and/or specialist institutes. Hence, according to the veterinary inspectorate and the veterinary scientific and specialist institute databases, five epizootiological regions are defined (Mirilović et al., 2005). In these areas, *Trichinella* infections have long been present in pigs and humans. The five mentioned epizootiological regions are West Bačka, South Bačka, Srem, Mačva-Kolubara and Podunavsko-Braničevska.

MATERIALS AND METHODS

Trichinella surveillance data (1994-2018) covered *Trichinella* cases registered in pigs and trichinellosis in humans. Data were obtained from the Veterinary Directorate (Ministry

of Agriculture, Forestry and Water Management) on the number and location of infected pigs. Data on human trichinellosis cases were obtained from the Institute for Public Health of the Republic of Serbia (Health Statistical Yearbook of Republic of Serbia 1995-2018).

Analysis of the obtained data was conducted using relative numbers for structure and dynamics, indices and descriptive statistical indicators. Trends in the changes in the number of infected pigs and human cases in the examined period are given as linear or polynomial equations. The most appropriate trend line was chosen according to the value of the correlation coefficient. Statistical analysis was performed with the support of the statistical package IBM SPSS 18.

RESULTS

Numbers of registered *Trichinella* infections in pigs and trichinellosis in humans in the five epizootiological regions and the remainder of Serbia from 1994 to 2018 are shown in Table 1. Between 1994 and 2018, 14,837 infected pigs were diagnosed in Serbia (Table 1). Out of that number, 12,954 (87.31%) infected pigs were diagnosed in the five observed epizootiological regions.

Table 1. Numbers of *Trichinella*-positive registered pigs and trichinellosis cases in humans in epizootiological regions and the remainder of Serbia from 1994 to 2018.

Epizootiological area	Area (km^2)	Infected pigs		Human cases	
		Number	%	Number	%
West Bačka	2,420	716	4.83	920	13.43
South Bačka	4,016	566	3.82	818	11.94
Srem	3,486	5,301	35.73	730	10.66
Mačva-and Kolubara	5,742	1,961	13.22	1,059	15.46
Podunavsko-Braničevska	5,113	4,410	29.72	626	9.14
Other Serbian regions	67,584	1,883	12.69	2,697	39.37
Total	88,361	14,837	100.00	6,850	100.00

The overall trend of *Trichinella* in pigs in Serbia from 1994 to 2018 is shown in Figure 1, and trend analysis reveals the occurrence of *Trichinella* in pigs in Serbia is falling. The average decrease in the number of infected pigs for the whole study period (1994-2018) was 47.65 pigs per year. During the study period, the disease in pigs had several cycles, but for the entire study period, the best-fit line was a fourth-degree polynomial, with a correlation coefficient of 0.91.

Partial trends of *Trichinella* occurrence in pigs in Serbia from 1994 to 2018 are shown in Figure 2. Between 1994 and 2018, the occurrence of *Trichinella* in pigs had several cycles (Figure 2). During the first five-year period (1994-1998), *Trichinella* occurrences

in pigs increased, on average, by 373.80 infected pigs annually. In the next five-year period (1999-2003), an opposite trend was found (Figure 2). With the exception of 1999, when there was an increase in the number of infected pigs, numbers of infected pigs declined throughout 1999-2003 by, on average, 17.70 infected pigs annually. Between 2009 and 2013, the average annual reduction in the number of infected pigs was 28.70 animals. The last period from 2014 to 2018 saw *Trichinella*-positive pig numbers increase again (the average annual increase was 2.20 pigs).

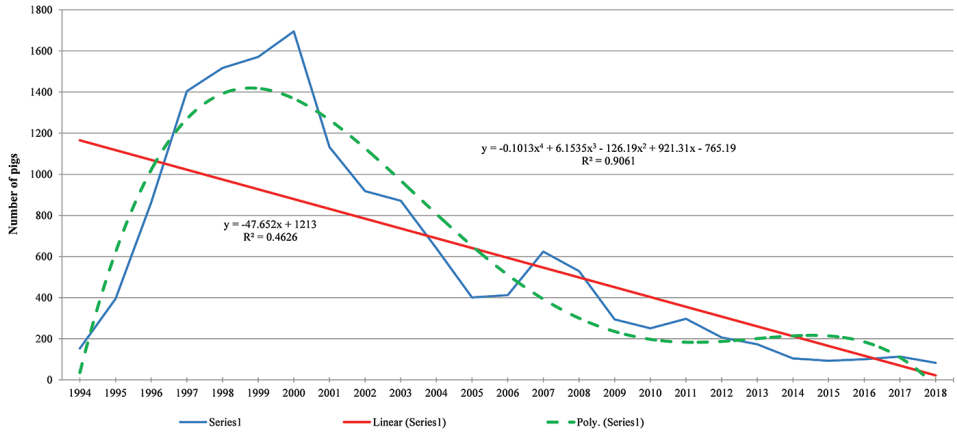

Figure 1. Occurrence and trend of *Trichinella*-positive pigs in Serbia from 1994 to 2018.

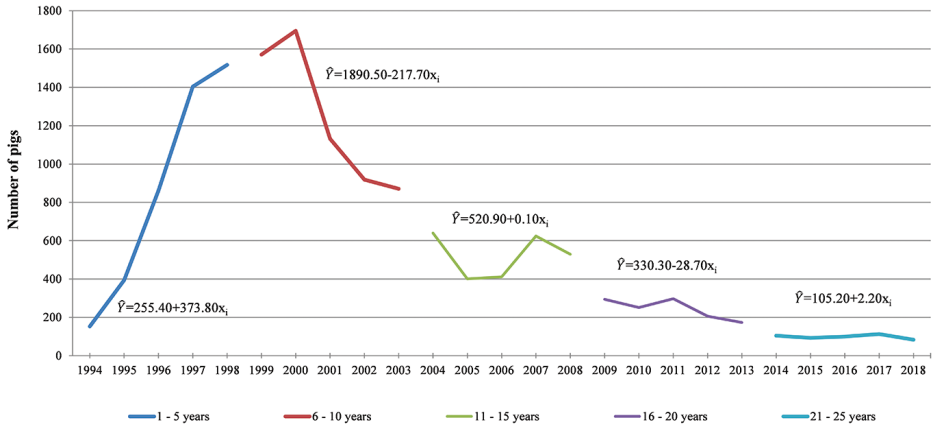

Figure 2. Partial trends of *Trichinella* in pigs in Serbia from 1994 to 2018

Among 6,850 reported human trichinellosis cases from 1994 to 2018, 56% (3,865) were in male and 44% (2,985) were in female patients. In the first half of the study period (1998-2005), a significantly higher number of patients (5,581) was reported than in the second half of the study period (2006-2018), when 1,269 people became

ill. The distribution according to sex of human patients with trichinellosis in Serbia from 1994 to 2018 is presented in Table 2.

Table 2. Distribution according to sex of patients with trichinellosis in Serbia from 1994 to 2018.

Year	Male (n)	Female (n)	Total (n)
1994	277	215	492
1995	396	395	791
1996	383	211	594
1997	407	359	766
1998	232	176	408
1999	296	263	559
2000	228	183	411
2001	218	165	383
2002	326	249	575
2003	98	80	178
2004	50	35	85
2005	185	154	339
2006	114	74	188
2007	115	62	177
2008	50	41	91
2009	26	24	50
2010	69	42	111
2011	82	45	127
2012	27	19	46
2013	56	39	95
2014	53	33	86
2015	50	32	82
2016	113	77	190
2017	7	8	15
2018	7	4	11
Total	3,865	2,985	6,850

The annual prevalences of human trichinellosis cases in Serbia from 1994 to 2018 are presented in Figure 3. Trend analysis showed the prevalence of trichinellosis in humans in the studied period declined by, on average, 27.84 cases annually. The best-fit line for the entire study period is a sixth degree polynomial with a correction coefficient of 0.85. The highest number of diseased patients was reported in 1997 (766 patients), while the lowest number was reported in 2018 when only 11 people became ill.

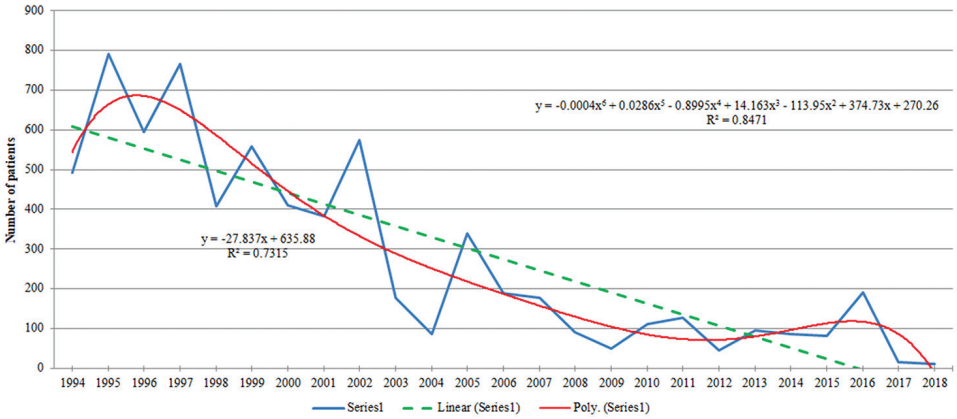

Figure 3. Annual prevalences and overall trend of human trichinellosis cases in Serbia from 1994 to 2018

The age structure of patients with trichinellosis in Serbia from 1994 to 2018 is shown in Figure 4. The highest number of patients were between 20 and 39 years old (1,227, i.e. 36.00% of all cases). Among the age groups, people from 20 to 60 years of age most often suffered from trichinellosis (Figure 4). During this life period, 4,742 people became ill, i.e. 69.3% of all patients.

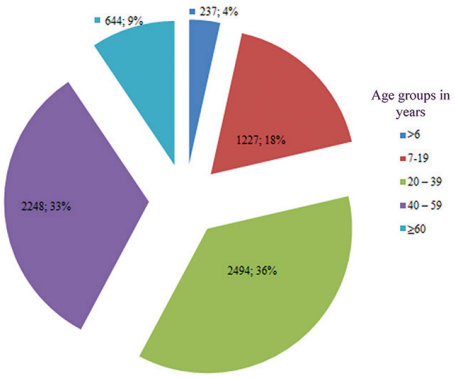

Figure 4. Age structure of patients with trichinellosis in Serbia from 1994 to 2018

The distribution according to reporting month of patients with trichinellosis in Serbia from 1994 to 2018 is shown in Table 3. In December-March, 5,427 people became ill, i.e. 79.23% of all reported trichinellosis patients. In January, 2,371 human cases were reported, i.e. 34.61% of all reported trichinellosis patients. In April-November, 1,423 people fell ill, i.e. 20.77% of all reported trichinellosis patients.

Table 3. Distribution of patients with trichinellosis according to reporting month in Serbia from 1994 to 2018.

Month	Patients with trichinellosis	
	Number	%
January	2,371	34.61
February	1,370	20.00
March	659	9.62
April	246	3.59
May	235	3.43
June	124	1.81
July	75	1.09
Avgust	37	0.54
September	59	0.86
October	166	2.42
November	481	7.02
December	1,027	14.99
Total	6,850	100.00

DISCUSSION

The five observed epizootiological regions in Serbia spread over a total area of 20,777 km^2, so cover 23.51% of Serbia's total area. Mačva-Kolubara is the largest epizootiological region (5,742 km^2), covering 27.63% of the five epizootiological regions, while the smallest epizootiological region is West Bačka, accounting for 11.65% of these examined regions. The total human population of the five observed epizootiological regions is 2,076,200, i.e. 27.69% of Serbia's total population.

The high percentage of infected pigs reported in the five epizootiological regions compared with *Trichinella* occurrences in pigs in the rest of Serbia is striking. Within these epizootiological regions, *Trichinella* occurred most frequently in the Srem and Podunavsko-Braničevska regions. Altogether, 65.45% of all *Trichinella*-positive pigs were diagnosed in these regions, but they account for only 9.72% of Serbia's territory. A similar situation was found for the occurrence of trichinellosis in humans. A total of 6,850 human cases were notified in Serbia during the study period. Of these, 4,153 human trichinellosis cases (60.63% of human cases in the country) were resident in the five epizootiological regions.

The overall decrease in the number of *Trichinella*-positive pigs is likely a consequence of intensive application of zootechnical measures in pork production and the continuous pest control measures implemented throughout most of Serbia. Nonetheless, there

was a large increase in the number of infected pigs in the first five years of this study, likely largely a result of the civil war in the Balkans, which resulted in a large migration of wild animals from their natural habitats to areas where domestic pigs live. Additionally, during this period there was a decline in intensive pig production, pigs were fed inadequate feeds, and biosecurity measures in pig breeding were not adequately applied. Probably as a consequence of all these circumstances, there was a constant increase in the number of *Trichinella*-infected pigs.

In the next five-year period (1999-2003), numbers of *Trichinella*-positive pigs generally declined, although with the exception of 1999, when the number of infected pigs increased. During this five-year period, pig production stabilized, a change from smallholder pig production systems to the modern indoor farming systems occurred, better rodent control and biosecurity measures were implemented and the animals were fed good quality diets.

After the turbulent first ten years of the examined period, there was a lull in the occurrence of *Trichinella* in pigs and a significantly smaller number of infected pigs were diagnosed in the next 15 years. From 2014 to 2018, *Trichinella*-positive pig numbers have increased again, but it is interesting to note that *Trichinella* in pigs now occurs in some new, non-epizootiological regions, primarily in the south and southeast parts of Serbia.

Declining numbers of human trichinellosis cases in Serbia could be due to raised awareness of the harmfulness and consequences of consuming insufficiently thermally processed meat and meat products. It seems likely that preventive measures, education programs, implementation of good production practices and regular inspection of slaughtered pig carcasses for *Trichinella* have been fruitful. The large polynomial of the best-fitting trend line for the human case data indicates the large, almost annual, variation in the incidence of trichinellosis in humans.

The age-dependent occurrence of trichinellosis in humans, whereby the majority of cases were between 20-60 years of age, was expected; people of this age are most often in contact with meat harbouring infectious *Trichinella*.

Trichinellosis in humans occurs seasonally in Serbia. Specifically, this disease occurs most frequently in the period from December to March. This was also expected because this is the month when meat and meat products are traditionally prepared for the coming year. People are probably most often infected by consuming undercooked cooked meat (tasting sausages, under-fried and roasted meat at the time of pork processing) or consuming cured products (sausages, ham, roast meat etc.) containing infectious larvae. In the other months (April to November), the infection rate is much lower since the intensity of pig slaughter and meat processing for household needs is also lower.

CONCLUSION

Altogether, 14,837 *Trichinella*-positive pigs were diagnosed in Serbia from 1994 to 2018. Of these infected pigs, 87.31% were diagnosed in five observed epizootiological regions. The number of *Trichinella*-positive pigs for the whole study period (1994-2018) decreased, even though the number of *Trichinella*-positive pigs increased during the first five years of the examined period.

A total of 6,850 people developed trichinellosis in Serbia from 1994 to 2018. Of these, 4,153 cases (60.63%) were resident in the five epizootiological regions. However, over the entire study period, numbers of reported trichinellosis human cases and *Trichinella* in pigs both decreased. This situation is likely the result of the implementation of continuous control and prevention measures. Trichinellosis mostly affected people in their most productive age range, from 20 to 60 years of age. Also most commonly, trichinellosis occurred in January, since in our study, 2,371 human cases were notified in this month, constituting roughly one-third of all patients in the examined 25-year period.

Acknowledgements

The paper was realized within the projects: TR 31034 " Selected biological hazards to the safety/quality of food of animal origin and the control measures from farm to consumer" supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

Authors contributions

MM was responsible for all aspects of the work in ensuring that questions related to the accuracy and integrity of the work are appropriately investigated; NT contributed to acquisition of data; VB gave contribution to data analysis and statistical interpretation of data; ĐS was involved in revision of the article for intellectual content; MN was responsible for critical evaluation and approval of the final version to be published; MS was responsible for feeding strategy and for the final revision of the article; ŠV has made substantial contribution to conception and design, and drafting the article.

Competing interests

The authors declare that they have no competing interest

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DISTRIBUCIJA POJAVE TRIHINELOZE SVINJA I LJUDI NA TERITORIJI REPUBLIKE SRBIJE U PERIODU OD 1994. DO 2018. GODINE

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Kratak sadržaj

Uvod. Trihineloza je zajednička bolest životinja i ljudi (više od sto vrsta sisara) uzrokovana parazitima koji pripadaju rodu *Trichinella*. Pripadnici ovog roda nađeni su na gotovo svim kontinentima i u svim klimatskim oblastima. Dugi niz godina traju intenzivna istraživanja na suzbijanju ove parazitoze, ali i pored velikog broja istraživanja i velikih novčanih sredstava uloženih u projekte za kontrolu i eradikaciju trihineloze, ona i u 21. veku predstavlja ozbiljan zdravstveni problem gotovo u celom svetu. Na osnovu procena nekih naučnika danas je u svetu parazitom *Trichinella* spp. zaraženo oko 27 miliona ljudi. Cilj našeg istraživanja bio je da se u periodu od 1994. do 2018. godine, ustanovi distribucija pojave treihineloze kod svinja i kod ljudi na teritoriji Republike Srbije, kao i da se uradi analiza trenda pojave ove bolesti kod ljudi i životinja.

Materijal i metode. Podaci prijavljenih slučajeva trihineloze u populaciji svinja i ljudi tokom dvadesetpetogodisnjeg perioda preuzeti su iz Uprave za veterinu i Instituta za javno zdravlje Republike Srbije. Podaci su analizirani primenom relativnih brojeva strukrura i dinamike, procentima kao i opisnim statističkim parametrima.

Rezultati i zaključak. Za vreme trajanja istraživanja na teritoriji Republike Srbije dijagnostikovano je ukupno 14.837 obolelih svinja, od tog broja na analiziranim epizootiološkim područjima dijagnostikovano je 87,31% obolelih svinja, a na ostaloj teritoriji Srbije samo 12,69%. Za ceo ispitivani period obolelo je ukupno 6.850 građana Srbije. Od tog broja 4.153 građana je obolelo na teritoriji analiziranih epizootioloških područja, što predstavlja 60,63% od svih obolelih građana na teritoriji Srbije. Najbolje ptilagođena linija trenda pojave trihineloze kod svinja je polinom četvrtog stepena, dok je najbolje prilagođena linija pojave trihineloze kod ljudi polinom šestog stepena. Trihineloza se kod ljudi najčešće javlja u periodu od decembra do marta.

Ključne reči: trihineloza, svinje, trend, distribucija.