TULAREMIA IN SOUTH-EASTERN SERBIA IN TWELVE-YEAR FOLLOW-UP

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Tularemia is a serious bacterial zoonosis caused by the highly infectious agent Francisella tularensis. Microbiological diagnosis of tularemia mainly relies on serology. The occurrence of a tularemia epidemic in the Southeast of Serbia in 1998/999 initiated an epidemiological as well as a clinical and microbiological research in this area.

Objective was establishing the correlation between the clinical-epidemiological and serological diagnosis of tularemia as well as the clinical and serological follow-up of patients in the period from 1 to 12 years since the disease onset.

From the beginning of 1999 until the end of 2011, 113 patients diagnosed with tularemia were examined. The control group was formed of 111 patients with lymphadenopathy of different origins. The following serological methods were used: microagglutination test (MAT), immunoensyme assays: ELISA (VMA, Belgrade), Serion ELISA IgG i IgM, Serazym ELISA and ELISA in house and immunochromatographic test (ICT).

Clinical-epidemiological diagnosis of tularemia was confirmed serologically in all 113 patients. The high sensitivity and specificity were found for all the examined tests. IgG Virion ELISA demonstrated the highest sensitivity (97.4%) and specificity (93.1%). IgG and IgM class of antibodies remained positive in the serum in a high percentage, even as long as 12 years from the infection. Oropharyngeal form (93.8%), with predominant unilateral cervical lymphadenopathy (91.5%), was the most common clinical form. Complications, such as supplicative lymphadenitis and recurrent lymphadenitis, were seen in 41.6% of patients.

A positive correlation between clinical-epidemiological and serological diagnosis of tularemia has been established. Serological findings must be interpreted only within the clinical picture of tularemia. A finding of IgM and IgG class antibodies or total antibodies of F. tularensis in the sera of patients without clinical disease manifestations, from one to 12 years from the disease onset, does not indicate an acute but a past infection. Acta Medica Medianae 2017;56(1):31-38.

Key words: tularemia, Francisella tularensis, diagnosis, microagglutination test, ELISA, immunochromatographic test

Introduction

Tularemia is a bacterial zoonosis, typically characterized by lymphonodal involvement. All around the world, there are different names for this disease: rabbit fever, rodent plague, deer-fly fever, Francis’ disease, O’Haras disease, epidemic lymphadenitis (1, 2).

It is caused by the highly infectious agent Francisella tularensis: gram negative coccobacillus and facultative intracellular pathogen. It involves two major species: F. tularensis subsp. tularensis (type A) – existing in almost whole North America, very virulent and a pathogen for many hosts, and F. tularensis subsp. holarctica (type B) – prevalent along the northern hemisphere, mainly in Eurasia, causing milder disease in humans and animals.

Human infection develops after the contact with infected rodents or vectors (tics, deer-flies, and mosquitoes), by contaminated food, water and aerosol. There is no human to human transmission (1-4).

After multiplication on the inoculation site (primary affect), Francisella tularensis spreads to regional lymph nodes (primary complex), then from the lymph nodes by the lymphohematogenous route to other organ systems. After acute inflammatory reaction on the site of inoculation,
similar as with other intracellular pathogens, a granuloma is formed, occasionally with caseous necrosis (1-4).

Depending on the site of infection, tularemia has six characteristic clinical forms: ulceroglandular, glandular, oculoglandular, oropharyngeal, pneumatic, and typhoidal.

Ulceroglandular tularemia is the most common type, representing 75% of all forms. The port of infection are lesions on the hand skin, followed by cubital and or axillar lymphadenitis, or tick bites, followed mostly by inguinal lymphadenitis (5).

Oropharyngeal (tonsilloglandular) tularemia is the predominant form of tularemia in our country (6) and the region. The primary affect is on the tonsilla. It looks like a unilateral ulceromembranous or ulceronecrotic pharingitis, with ipsilateral lymph node enlargement.

Glandular tularemia is pathogenetically identical to ulceroglandular and oropharyngeal forms, but with a weakly expressed primary affect that remains unrecognised.

Secondary skin manifestations are also possible in tularemia, and they are often misdiagnosed or overlooked. There are maculopapular, vesi-copapular, urticarial rash, as well as numerous immune-related skin changes, including erythema nodosum, erythema multiforme and Sweet’s syndrome (7).

The most frequent complications of tularemia are lymph node suppuration and recurrant lymphadenitis (8).

The diagnosis of tularemia is based on the recovery of an isolate, antigen or molecular detection and serology. Serological tests represent the gold standard in the diagnosis of tularemia. Agglutination in one titer $\geq 1:160$ or microagglutination $\geq 1:128$, or a four-fold or higher increase of the titer in consequent sera samples confirm the diagnosis (5, 9). Immunoenzyme assay (ELISA) is more sensitive and specific than agglutination tests and this test can detect individual immunoglobulin classes (10-12). Immunochromatographic test is fast, very sensitive and specific (13, 14). Indirect immunofluorescence test (IIF) is very specific and it can detect specific antibodies as well as antigens in the serum and in other clinical samples of patients (15). The tests used for antigen confirmation are direct immunofluorescence test (DIF) and immunohistochemistry (IHH) used in animal models with the use of monoclonal antibodies against $F. tularensis$ antigen (16, 17). Molecular methods such as PCR are available in reference laboratories (18).

Objective

Establishment of a correlation between the clinical-epidemiological and serological diagnosis of tularemia, as well as clinical and serological follow-up of tularemia patients in the period from one to twelve years.

Patients and methods

From the beginning of 1999 until the end of 2011, 113 patients diagnosed with tularemia were examined. The control group was consisted of 111 patients with lymphadenopathy of different origin. Tularemia patients were clinically observed and serologically monitored using adequate tests, in the period mentioned above. In newly diagnosed patients, paired serum samples were taken: the first sample was taken from 2nd to 4th week from the beginning, and the second, from 4th to 8th week.

Clinical-epidemiological, microbiological-immunodiagnostic examination were conducted in all patients. Serological methods included: micro-agglutination test (MAT), immunoenzyme assays: ELISA (VMA, Belgrade), Serion ELISA IgG i IgM, Serazym ELISA and ELISA in-house (Friedrich-Loeffler Institute, Jena) and immunochromatographic test (ICT)-VIRapid.

The multiple research was performed at the Clinic for Infectious Diseases, Clinical Centre Niš, primary care units in Sokobanja, Pirot, Aleksinac, Military Medical Academy in Belgrade, “Neolab” laboratory in Niš and Federal Veterinary Institute for bacterial zoonoses -Friedrich-Loeffler, Jena, Germany.

The results of the study were systematized and presented in tables and graphs (Excel 2007, Word 2007), processed using statistical descriptive and quantitative methodology (SPSS 16.0 for Windows 2007).

Results

The total of 144 patients with differential diagnosis of tularemia were clinically observed, diagnosed and monitored in the interval from 1 to 12 years, since the beginning of 1999 until the end of 2011. In order to definitely confirm the diagnosis of tularemia, the clinical, epidemiological suspicion had to be confirmed by serological immunodiagnostic tests. The clinical criteria included dominant unilateral lymphadenopathy and/or tonsillogpharyngitis with fever and possible skin le-
sions, mostly on hands and shins. The most frequent clinical form was oropharyngeal (93.8%): with tonsilloglandular (47.8%) and glandular (46%), manifested as a predominant unilateral form (92%).

The most common clinical manifestation of tularemia was lymphadenopathy in 95.6% of patients, predominantly cervical (88.5%) and unilateral (93%) (Figure 1). The unilateral cervical lymphadenopathy form is statistically significantly more frequent in tularemia patients, in comparison to the control group (p < 0.05).

Tonsillopharyngitis was diagnosed in 54 (47.8%) patients with a predominant unilateral localization in 44 (81.5%) patients. The most frequent form was unilateral exudative tonsillopharyngitis (63%) (Figure 2).

Fever was present in 100 of total 113 tularemia patients (88.5%). Two thirds of all patients (75%) presented with high fever > 38°C. Hyperpyrexia (≥ 39.1°C) was significantly more widespread in tularemia cases compared to the control group (p = 0.005). The fever of tularemia patients lasted for 7.5 days on the average.

The most frequent types of skin manifestations were erythema exudativum multiforme (25%) (Figure 3), erythema nodosum (25%) and ulceration as primary affect. The skin changes were located mostly on the hands (44.4%) and shins (37%).

Complications occurred in 47 out of 113 patients (41.6%). The most common complication was suppurative lymphadenitis (38%), followed by recurrent lymphadenitis (16.8%). Suppurative lymphadenitis was statistically more common in tularemia cases, than in the control group (p < 0.05) (Figure 1).

The patients with clinical-epidemiological diagnosis of tularemia (n = 113) were observed and serologically monitored in the period from one to twelve years. The results of the previous serum testing by MAT (VMA) and ELISA (VMA) were compared with the results of testing with commercial tests IgG Serion ELISA, IgM Serion ELISA, Serazym ELISA, ELISA in house test, and noncommercial ELISA in house test. The results of testing with indirect-immunofluorescence test (IIFT) were used to detect the antigens of F. tularensis in pharyngeal swabs and lymph node punctates (6).

The schematic presentation of comparative immunodiagnosis is given in Diagram 1.

In patients suffering from tularemia (n = 113), the final results of repeated serum testings by MAT were as follows: 87 positive, 5 negative and 10 borderline findings. In the remaining 11 patients, MAT testing was not done. Of all 15 sera in which the specific antibodies on F. tularensis were not found by MAT, in 11 of them ELISA (VMA) test was positive. Indirect immunofluorescence tests were positive in pharyngeal swabs and lymph-node punctates in the remaining 4 patients. All 15 sera negative by MAT were analyzed with the tests mentioned above (in 13 patients all 6 tests were positive; in one patient 5 tests were positive; in one patient, 4 tests were positive). The sera of all 11 patients not tested with MAT were positive after testing with IgG Serion ELISA, IgM Serion ELISA, Serazym ELISA, ELISA in house and VIRapid (Diagram 1).

In the control group, the results of previous testing by MAT were obtained: in 23 patients tularemia was excluded, in 2 patients tularemia was confirmed and 6 patients were not tested. In the following sera simultaneously tested with five immunodiagnostic tests, tularemia was excluded in 2 patients who were previously positive on ELISA (VMA). Of 23 patients with negative sera on MAT, ELISA (VMA) was positive in the sera of 5 patients. After the simultaneous testing with immunodiagnostic tests, tularemia was excluded in all 5 patients. In all 6 patients who were not previously tested by MAT, tularemia was excluded by immunodiagnostic tests (Diagram 1).

The characteristics of the diagnostic tests performed in all the examined patients were shown in Table 1. The results indicated the highest sensitivity in Serazym ELISA (97.4%) and VIRapid (97.4%), then IgG Serion ELISA (95.5%), IgM Serion ELISA (92.2%), and the lowest in In-house ELISA (77.9%).

Regarding specificity, the highest specificity was noted in In-house ELISA (94.4%) and IgG Se-
Tularemia in south-eastern Serbia in twelve-year follow-up

Diagram 1. Comparative immunodiagnosis of the patients affected by tularemia and control group

Table 1: Characteristics of diagnostic tests in all examined serum samples

|                  | IgG Serion ELISA | IgM Serion ELISA | Serazym ELISA | In-house ELISA | VIRapid |
|------------------|------------------|------------------|---------------|----------------|---------|
| No of serum      | 213              | 211              | 261           | 262            | 262     |
| samples          |                  |                  |               |                |         |
| Sensitivity      | 0.9548           | 0.9221           | 0.9742        | 0.7792         | 0.9740  |
| Specificity      | 0.9310           | 0.8421           | 0.6792        | 0.9444         | 0.8519  |
| PPV*             | 0.9737           | 0.9404           | 0.8162        | 0.9524         | 0.9036  |
| NPV**            | 0.8852           | 0.8000           | 0.9474        | 0.7500         | 0.9583  |
| Test efficiency  | 0.9484           | 0.9005           | 0.8544        | 0.8473         | 0.9237  |

* PPV- positive predictive value
** NPV- negative predictive value

Abbreviations:

DIF - direct immunofluorescence
ELISA - enzyme-linked immune sorbent assay
F. tularensis - Francisella tularensis
ICH - immunochromatographic test
IHC - immunohistochemistry
IIF - indirect immunofluorescence
MAT - microagglutination test
VMA - engl. MMA - Military Medical Academy

The highest positive predictive value was found in IgG Serion ELISA (97.37%), then In-house ELISA (95.2%) and IgM Serion ELISA (94%). The highest negative predictive value was seen in VIRapid (95.8%) and Serazym ELISA (94.7%) tests. The highest diagnostic efficacy was observed in IgG Serion ELISA (94.8%), VIRapid (92.4%) and IgM Serion ELISA (90.0%).

The best test to confirm the diagnosis of tularemia, according to the factors of sensitivity and specificity, was IgG Serion ELISA test (Table 2).

Analyzing the presence of IgG and IgM antibodies in the serum of patients in correlation with the period of time (1-12 years), the persistence of positivity for longer period of time was seen in both classes of antibodies. IgG Serion test showed a 100% of positivity of IgG antibody, until 9 years of the disease onset. After that, the percentage of positivity slightly decreased; after 10 years it was 85.7%. IgM class of antibody presented high and irregular activity during the follow-up period. The finding of IgM positivity varied from 71.4% to 100.0% (Table 2).
Table 2.: Finding of F. tularensis IgG i IgM antibodies in a 11-year period

| Time period (years) | No patients n | Positive finding IgG n (%) | Positive finding IgM n (%) |
|---------------------|---------------|----------------------------|----------------------------|
| 1                   | 5             | 5 (100.0)                  | 5 (100.0)                  |
| 2                   | 6             | 6 (100.0)                  | 5 (83.3)                   |
| 3                   | 5             | 5 (100.0)                  | 5 (100.0)                  |
| 4                   | -             | -                          | -                          |
| 5                   | 7             | 7 (100.0)                  | 5 (71.4)                   |
| 6                   | 14            | 14 (100.0)                 | 14 (100.0)                 |
| 7                   | 10            | 10 (100.0)                 | 9 (90.0)                   |
| 8                   | 16            | 16 (100.0)                 | 15 (93.8)                  |
| 9                   | 1             | 1 (100.0)                  | 1 (100.0)                  |
| 10                  | 7             | 6 (85.7)                   | 7 (100.0)                  |
| 11                  | 17            | 16 (94.1)                  | 14 (82.4)                  |
| Total               | 88            | 86 (97.7)                  | 80 (90.9)                  |

Discussion

During the first epidemic of tularemia in the Sokobanja region in 1999, the oropharyngeal form of tularemia was not recognized (6, 19). The disease was associated with an excessive regional neck lymphadenitis and/or tonsillolaryngitis; although, remarkably, the lymph node enlargement was most often unilateral, as well as tonsillo-llitis. Even though, it was the most common form (93.8 %) and typically unilateral (92%), oropharyngeal form could often be misinterpreted as some other infectious or non-infectious diseases, such as streptococcal angina, infectious mononucleosis, tuberculosis and lymphoma. An absence of response to B-lactam antibiotics, raised suspicion that it was some other disease, which was in accordance with the experience of other authors (20-22).

The data on the most frequent cervical unilateral localization of lymphadenopathy and tonsillolaryngitis, mostly exudative unilateral (6, 19, 23), corresponded to the results of those authors who described oropharyngeal tularemia as the most common form (in Bosnia, Bulgaria and Turkey) (24-27). On the contrary, the involvement of axillary and inguinal lymph nodes is most frequent in ulceroglandular tularemia, as reported by other authors (28, 29).

In the first cases of tularemia, rash was predominant in the clinical picture, especially on the hands, which caused diagnostic dilemmas (19) (Figure 3). The most frequent skin manifestations were erythema exudativum multiforme (25%) and erythema nodosum (25%). The similar skin changes, erythema nodosum, macular, popular and morbilliform rash, were reported by Golubović. Erythema multiforme-like skin lesions on the upper and lower extremities were noticed in 14% of tularemia patients, as reported by Christensen et al. (1984) (30). According to Akdis et al. (1993), 14.1% of cases developed erythema nodosum. These patients had a high level of polyclonal circulating immune complexes in comparison to the patients without skin lesions (31).

The complications such as suppurative lymphadenitis seen in 38% of our patients, were also described in Turkey (40%), caused by a delayed diagnosis and treatment during the epidemic of oropharyngeal form of tularemia type B (8). Recurrent lymphadenitis, noted in 16.8% of our patients, was also reported by Golubović et al. (1996) in the Republic of Srpska in 1995. According to this author, 17% of 141 patients had a recurrence, in some cases recurring 2-3 times (24).

SeroLOGY is commonly used to confirm tularemia due to low sensitivity of bacterial culture and the fact that molecular methods are not widely available. The results of serological tests should always be interpreted in the context of clinical suspicion of tularemia. Serological analysis should only be performed in patients with a real possibility of having tularemia, and not as a screening test for feverish patients.

A negative result of MAT, in the case of a clinically-epidemiologically clear picture of tularemia does not exclude tularemia, but suggests that higher sensitivity tests, such as ELISA and immune blot, should be used (15, 32).

In an early phase of the infection, false-negative results of MAT are often seen, and it is thus necessary to test one more serum sample after two weeks. While some patients have never developed seroconversion, others have stayed seropositive for years. These seropositive patients could have had crossed antibodies because of the infections with other bacteria (Yersinia, Brucella) (33).

The latest results of serum sample examinations with commercial (IgG Serion ELISA, IgM Serion ELISA, Serazym ELISA) and non-commercial (ELISA in-house) immunoenzyme assays have shown a higher sensitivity and specificity of all tests (sensitivity 98-99%, specificity 90-97%) compared with the results from the previous testing with ELISA (VMA) (sensitivity 93%, specificity 94.4 %) (6, 15).

It has been confirmed that ELISA is more sensitive and specific than agglutination tests (10, 34). The advantage of ELISA is that it can determine separately the different antibody classes: IgM, IgG and IgA. In contrast to agglutination which can detect mainly IgM antibodies and at least two serum samples are required to confirm the disease, ELISA requires only one sample for diagnosis. Furthermore, ELISA can detect antibodies in infection earlier compared to agglutination; the percentage of detection during the first week is 43%, vs 11% for agglutination (35). The disadvantage of this method is that it can not differentiate between an acute and past infection, because all classes of antibodies, IgM, IgA and IgG, rise and decline at the same time (18). The monitoring of IgG and IgM titer levels and determination of the IgG/IgM ratio, can be important in detecting the onset of infection (34).

According to results of Koskela, the antibody responses against F. tularensis are generally detectable 10-20 days post-infection. Among the three used tests, ELISA, agglutination test and comple-
ment-fixation ELISA, the most efficient is ELISA IgM, IgA and IgG for an early serodiagnosis of tularemia (36).

Analyzing the tests results, it was confirmed that most tests shared similar high sensitivity and specificity values. Based on the estimation of accordance between all the tests, the best accordance was seen for IgG Serion ELISA and Serazym ELISA (k = 0.802), then IgM and VIRapid (k = 0.780), IgG and IgM Serion ELISA (k = 0.766), IgM and VIRapid (k = 0.780), and IgG and VIRapid (k = 0.760). It was established, that the best test to confirm the diagnosis of tularemia, based on sensitivity and specificity, was IgG Serion ELISA test.

In our research, the persistence of both IgM and IgG antibodies was seen in the sera of patients, even as long as 12 years after the infection. This is in agreement with the results of several authors who monitored humoral immunity in a longer period of time after natural infection (Ericsson: 25-year follow-up; and Koskela: 8-year follow-up) (33, 36).

Patient is considered to suffer from tularemia when he has clinical symptoms compatible with tularemia, as well as a positive serology on F. tularensis antibodies. The persistence of antibody positivity for longer periods of time without clinical manifestations of the disease, indicates a prior, not a current infection. In our experience, there was not any cases of reinfection, and thus it was not necessary to control consecutive serum samples in two weeks, nor to determine the IgG/IgM ratio.

The reason for such an extremely long persistence of F. tularensis antibodies after infection, shown by different authors, is still under investigation (33, 37). According to the study by Ericsson, the humoral immune response decreases 25 years after natural infection with F. tularensis. Serum agglutinins titers were low: out of 53 patients, only two had titers >40 (33). The role of serum antibodies which develop after the infection is less known (37).

Tularemia is not present in a latent form and the patient can not be reinfected even in a state of immune deficiency. The patients are completely cured from this bacterial disease.

Conclusion

Tularemia in South-eastern Serbia is an endemic disease, according to the earlier clinical-epidemiological studies (6). A positive correlation between the clinical-epidemiological and serological diagnosis of tularemia has been established. Serological findings have to be interpreted only within the context of clinical diagnosis of tularemia, not independently and separately from the clinical picture. A detection of IgM and IgG classes of antibodies or total antibodies to F. tularensis in the sera of patients without clinical manifestations of the disease, up to 12 years from the infection onset, does not indicate a current, but a past infection.

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Tularemia in south-eastern Serbia in twelve-year follow-up

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Tularemia is a serious bacterial zoonosis caused by the highly infectious agens Francisella tularensis. The microbiological diagnosis of tularemia is usually based on serological tests. The appearance of tularemia epidemic in Serbia in 1998/1999, year initiated both epidemiological and clinical and microbiological investigations in this area.

The purpose of the work was to determine the correlation between clinical-epidemiological and serological diagnosis of tularemia and clinical and serological follow-up of patients in a period from one to 12 years from the onset of illness.

The study included a group of 113 patients with tularemia diagnosed in period from the beginning of 1999 to the end of 2011. The control group consisted of 111 patients with lymphadenitis of various etiologies. The used serological tests were: microagglutination test (MAT), immunoenzymatic tests: ELISA (VMA) and ELISA "in house", Serion ELISA classic Francisella tularensis IgG and Serion ELISA classic Francisella tularensis IgM, Serazym Anti-Francisella tularensis ELISA and immunochromatographic test (ICT)-VIRapid. 

All 113 patients with clinical-epidemiological diagnosis of tularemia were confirmed serologically. The test showed high sensitivity and specificity. ELISA IgG Serion test showed the highest sensitivity (97.4%) and specificity (93.1%). IgM and IgG antibodies were maintained in serum of patients in a high percentage and after 12 years from infection. Orofaringeal tularemia is the most frequent clinical form of the disease (93.8%) with a dominant unilateral cervical lymphadenitis (91.5%). Complications were noted in 41.6% of patients, with the greatest frequency of draining and recurrent lymphadenitis.

A positive correlation was determined between clinical-epidemiological and serological diagnosis of tularemia. The results of serological tests should be interpreted in the context of clinical picture of tularemia. The presence of IgM and IgG antibodies or specific antibodies to F. tularensis in the serum of patients without clinical picture after 12 years from the onset of illness is not a sign of acute, but delayed disease.

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Ključne reči: tularemija, Francisella tularensis, dijagnoza, mikroaglutinacioni test, ELISA, imunohromatografski test

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