Detection of Mycoplasmal Infections in Blood of Patients with Rheumatoid Arthritis

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SUMMARY

Objectives: Mycoplasmal infections are associated with several acute and chronic illnesses. Some mycoplasmas can enter a variety of tissues and cells and cause system-wide or systemic signs and symptoms.

Methods: Patients (14 female, 14 male) diagnosed with Rheumatoid Arthritis (RA) were investigated for mycoplasmal infections in their blood leukocytes using a forensic Polymerase Chain Reaction (PCR) procedure. Amplification was performed with genus- and species-specific primers, and a specific radio-labeled internal probe was used for Southern hybridization with the PCR product. Patients were investigated for presence of *Mycoplasma spp.*, and positive cases were further tested for infections with the following species: *M. fermentans*, *M. hominis*, *M. pneumoniae* and *M. penetrans.*

Results: The *Mycoplasma spp.* sequence, which is not entirely specific for mycoplasmas, was amplified from the peripheral blood of 15/28 patients (53.6 %), and specific PCR products could not be detected in 13 patients (46.4 %). Significant differences (p<0.001) were found between patients and positive healthy controls in the genus-test (3/32) and in the specific tests (0/32). Moreover, the incidence of mycoplasmal infections was similar in female and male patients. Using species-specific primers, we were able to detect infections of *M. fermentans* (8/28), *M. pneumoniae* (5/28), *M. hominis* (6/28) and *M. penetrans* (1/28) in RA patients. In 36% of the patients we observed more than one mycoplasma species in the blood leukocytes. All multiple infections occurred as combinations of *M. fermentans* with other species.

Conclusions: The results suggest that a high percentage of RA patients have systemic mycoplasmal infections. Systemic mycoplasmal infections may be an important cofactor in the pathogenesis of RA, and their role needs to be further explored.

Introduction

Mycoplasmas are the smallest self-replicating, pleotrophic bacteria that lack cell walls [i, ii]. The largest group of the class *Mollicutes* is divided into more than 100 mycoplasma species, which are further subclassified into various strains. Mycoplasmas are often found as extracellular parasites attached to the external surfaces of host cells, but some species invade host tissues and cells, and replicate intracellularly.

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These microorganisms can produce a variety of effects on host cells and tissues. Besides affecting cell growth and morphology, mycoplasmas are able to alter metabolic, immunological and biochemical functions [iii].

Mycoplasmas are commonly found in the oral cavity and as symbiotic gut flora. Formerly, mycoplasmas were considered as relative benign microorganisms with a low pathogenic potential. When they penetrate into blood vessels and colonize major organs, certain species can, however, cause acute and chronic illnesses. Some mycoplasmas, such as *M. penetrans*, *M. fermentans* and *M. pirum*, can enter a variety of tissues and cells and cause a broad spectrum of signs and symptoms [iii]. Mycoplasmas have also been shown to have a complex relationship with the immune system [iv]. They are very effective at evading host immune responses, and synergism with other infectious agents has been seen. The best known species is *M. pneumoniae*, which can cause atypical pneumonia [v, vi]. Mycoplasmal infections can present as different clinical disorders with acute and chronic signs and symptoms. Although many of these signs and symptoms are nonspecific, they seem to be related, in part, to immunological or autoimmunological responses. For example, using culturing techniques *Ureaplasma urealyticum*, *M. pneumoniae* and *M. salivarium* have been localized in the joint tissues of patients with rheumatoid diseases [vii]. Hoffman et al. [viii] found serological evidence for active and inactive mycoplasmal infections in patients with rheumatoid arthritis (RA) and juvenile RA, but they could not detect mycoplasmal DNA in the synovial fluid of these patients using polymerase chain reaction (PCR). Other studies observed immunological evidence for mycoplasmal infections in RA patients [ix, x].

We have begun to examine patients with chronic illnesses for the presence of systemic mycoplasmal infections. In recent studies we have shown that patients with Chronic Fatigue Syndrome (CFS) and/or Fibromyalgia Syndrome (FMS) have a much higher incidence of mycoplasmal infections in their blood leukocytes than healthy controls without clinical signs and symptoms [xi, xii, xiii]. We hypothesized that chronic mycoplasmal infections might be also related to the pathogenesis of other chronic illnesses, such as RA.

Mycoplasmal infections are usually diagnosed by serological procedures or culture techniques [xiv, xv]. Both of these techniques are very limited in their sensitivity, and thus mycoplasmal infections are often underdiagnosed or misdiagnosed [xvi]. The introduction of mycoplasma-specific primers in PCR enables sensitive and specific detection of mycoplasmal infections and discrimination between different mycoplasma species. Using PCR techniques the presence of mycoplasmas was investigated in synovial fluids of patients with RA and other chronic arthritides. Schaeverbeke et al. [xvii] showed that *M. fermentans*, but not *M. penetrans* was detectable in 20% of these patients and other types of arthritis of unknown causes agent, but not in patients with reactive, posttraumatic or chronic juvenile arthritis. Additionally, *M. genitalium* was found in some RA patients [xviii]; however, the sensitivity of the conventional PCR procedures was not satisfying [xix]. The forensic PCR method that we use to identify mycoplasmal infections is very sensitive and highly specific [xi].

In this preliminary study, we report on the detection of mycoplasmas in blood leukocytes of patients with RA. Using a sensitive forensic PCR method with genus-specific primers, we investigated blood samples for the presence of any type of mycoplasmal infection. Using species-specific primers, we then tested for the presence of several mycoplasma species.

Materials and Methods

Patients

Blood samples from 28 patients (50% female, 50% male), diagnosed with RA were investigated for mycoplasmal infections in their blood leukocytes. According to the American College of Rheumatology modified criteria were used for patient's diagnosis [xx]. All patients were examined by a rheumatologist (A.R.F.) and all patients fulfilled the ACR classification criteria for RA. Patients' age ranged between 22

and 65 years (median 42 years). The duration of RA history was 16 to 300 months (median=149 months). All patients had no antibiotic treatments for at least 6 weeks before the blood was drawn.

Specimens

Specimens were collected and treated as previously described [xi]. Briefly, blood was collected in citrate-containing tubes and immediately brought to ice bath temperature. Samples were shipped refrigerated or on wet ice by over night courier. Whole blood (50 µl) or blood leukocytes were used for preparation of DNA using Chelex (Biorad) as follows. Blood cells were lysed with nanopure water (1.3 ml) at room temperature for 30 min. After centrifugation at 13,000 x g for 2 min, the supernatants were discarded. Chelex solution (200 µl) was added, and the samples were incubated at 56°C and at 100°C for 15 min each. Aliquots from the centrifuged samples were used immediately for PCR or stored at -70°C until use.

Amplification

Amplification of the target sequences (Table 1) was performed in a total volume of 50 µl PCR buffer (10 mM Tris-HCl, 50 mM KCl, pH 9) containing 0.1% Triton X-100, 200 µm each of dATP, dTTP, dGTP, dCTP, 100 pmol of each primer, and 0.5-1 µg of chromosomal DNA. Purified Mycoplasmal DNA (0.5-1ng of DNA) was used as a positive control for amplification. The amplification was carried out for 40 cycles with denaturing at 94°C. Annealing was performed at 60°C (genus-specific primers and *M. penetrans*) or 55°C (*M. pneumoniae*, *M. hominis* and *M. fermentans*). Extension temperature was 72°C in all cases. Finally, product extension was allowed at 72°C for 10 min. [xxi-xxiii]. Negative and positive controls were used in each experimental run.

Southern Blot Confirmation

The amplified samples were run on a 1% agarose gel containing 5 µl/100 ml of ethidium bromide in TAE buffer (0.04 M Tris-Acetate, 0.001 M EDTA, pH 8.0). After denaturing and neutralization, Southern blotting was performed as follows. The PCR product was transferred to a Nytran membrane. After transfer, UV cross-linking was performed. Membranes were prehybridized with hybridization buffer consisting of Denhardt's solution and 1 mg/ml salmon sperm as blocking reagent. Membranes were then hybridized with ^{32}P-labeled corresponding internal probe (10^7 cpm per bag) (see Table 1). After hybridization and washing to remove unbounded probe, the membranes were exposed to autoradiography film for 7 days at -70°C.

Results

For the detection of mycoplasmal infections in blood leukocytes, we first used genus-specific primers. The *Mycoplasma spp.* sequence was amplified from DNA extracted from the peripheral blood of 15/28 (53.6 %) patients, whereas specific PCR products were not detected in the 13 negative patients (46.4 %). Results were similar in female and male patients. In 32 healthy controls without any clinical signs and symptoms, positive results were shown in 3 cases (9.4%) for *Mycoplasma spp.* test but not for the other species-specific tests (0/32).

Specific primers for *M. fermentans*, *M. pneumoniae*, *M. penetrans* and *M. hominis* were used to detect species-specific mycoplasmal DNA by PCR. In 10/15 patients with a positive signal for *M. spp.* we detected one or more mycoplasma species, but in 5 positive patients we were unable to find at least one of the four tested species. The incidence of infections with *M. fermentans* (8/28), *M. pneumoniae* (5/28) and *M. hominis* (6/28) was similar. *M. penetrans* was found in only one patient. In 36% of the patients that tested positive for the general mycoplasmal infection, we observed more than one species in the blood leukocytes. These multiple infections occurred as combinations of *M. fermentans* with other species. Single infections were found in 5 patients (*M. fermentans* n=2; *M. hominis* n=2; *M. pneumoniae* n=1), but were not observed with *M. penetrans*. All four species were detected in one patient.

Although the GPO-1 and UNI-sequences are capable of a few possible cross-reactions with mycoplasma-related organisms, the conditions used yielded specific products for mycoplasmas as shown by van Kuppeveld et al. [xxiv] and Dussurget et al. [xxv]. That the patients we examined had mycoplasmal infections was confirmed by species analysis using PCR. Using the *M. fermentans*-specific primers SB1 and SB2 from the *tuf* gene we found a single band of 850 bp size that hybridized only with the ^{32}P-labeled internal probe SB3. Similar results were obtained for the other mycoplasma species (see figure 1). To examine the reliability of the method we performed multiple assays (repeated 3-7 times) on 40 samples with other diagnoses. All results were completely reproducible. In three cases, the sixth and seventh repeat of an initial positive result produced only a week but positive signal due to degradation of DNA.

Fresh blood and immediate DNA preparation resulted in better results than blood that was processed after a period of time at room temperature. Six positive blood samples were divided into 5 aliquots each and stored at room temperature for different time intervals (processed immediately or after 1, 2, 4, or 7 days). Over time the PCR signal decreased. In all samples that showed positive results in fresh DNA preparations, the PCR signal became weak after 2 days of blood storage at room temperature. After 4 days, negative results were obtained in 4 cases, whereas the other two samples showed very faint bands. No specific PCR product was detectable after one week. Additionally, blood collected in tubes containing citrate gave better results than blood collected in acid-EDTA.

The sensitivity of mycoplasma detection by the described method was assessed by the detection of control mycoplasma DNA and by internal Southern hybridization using mycoplasma-specific probes. Using serial dilutions of mycoplasma DNA, the method was able to detect as low as 1 fg of DNA [xi]. In other experiments, *M. fermentans* was added to control blood samples at various concentrations. We were able to detect specific products down to 10 ccu/ml blood. Thus with the use of specific Southern hybridization this PCR procedure can result in specific test results of high sensitivity, down to the presence of approximately a single microorganism in a clinical sample.

In our experience, conventional PCR yields similar results to forensic PCR with extracellular mycoplasma, but not with clinical samples that contain intracellular mycoplasmas. The reason for this is not known, but it could be due to inhibitors present in the clinical samples or to loss of mycoplasma DNA in the conventional extraction procedures due to protein complexing.

Discussion

Although the underlying causes of RA are not known, RA and other autoimmune diseases could be triggered, at least in part, by infectious agents. The remarkable clinical and pathological similarities between certain infectious diseases in animal species and those of some human rheumatic illnesses, such as RA, have encouraged the search for a microbial etiology for these syndromes. A long list of microorganisms, including aerobic and anaerobic intestinal bacteria, several viruses and mycoplasmas have been proposed as important in these illnesses [xxvi]. Although several initial findings on many etiological agents were corroborated by further studies, the concept of a microbial trigger for RA is attractive. Recently, there has been increasing evidence that mycoplasmas may, in part, play a role in the genesis of arthritis [xxvii].

In the present pilot study we detected several mycoplasma species in blood leukocytes of patients suffering from RA. Although the patient numbers in these studies were not large, using a highly sensitive and specific PCR technique we were able to detect mycoplasmal DNA in more than 50% of patients. Mostly we detected *M. fermentans*, and *M. penetrans* was found in only one patient with multiple mycoplasmal infections. Recently, similar findings were published using synovial fluids and joint tissue specimens [xvii]. Additionally, we observed infections with *M. pneumoniae* and *M. hominis*. The presence of trace amounts of mycoplasmal antigens for these species or specific antibodies against mycoplasma species were found in other studies using immunological methods [x, xiv]. Interestingly, we detected multiple infections with several mycoplasma species in a high percentage of our patients, but these multiple infections were seen only in combination with *M. fermentans* infections. The UNI- and

GPO1 primer are not totally genus-specific. However, the conditions used for PCR yield amplification products with a high degree of specificity and sensitivity [xxiv, xxv]. To overcome the problems regarding the limited specificity we confirmed the results for the *Mycoplasma spp.* assay with highly species-specific assays. We were able to identify at least one mycoplasma species in 10 of 15 patients where the general test was positive. In the remaining 5 patients it is more likely that other mycoplasma species were responsible for the positive amplification signal, such as *M. arthritidis*, rather than cross-reactions with other closely related microorganisms. However, the limited specificity of the general test cannot completely rule out such cross-reactivity. Future studies will include more mycoplasmal species using highly species-specific primers.

Since little is known about the possible involvement of mycoplasmas in the pathogenesis of chronic diseases, it remains uncertain whether our findings represent a causal agent, cofactor, or secondary superinfection in patients with immundisturbances. However, mycoplasmas are able to induce immundysfunctions and autoimmune reactions. Thus, mycoplasmal infections may be, in part, involved in the pathogenesis of RA.

Mycoplasmal infections were reported in patients with various inflammatory diseases, such as endocarditis [xxviii], pericarditis [xxix] or encephalomyelitis [xxx], where immunological or autoimmunological phenomena coexist. Although the basis for these infections is not well understood, it is apparent that several species of pathogenic mycoplasmas are endowed with a sophisticated genetic machinery for altering their surface attributes. This surface phenotypic variation is thought to play a key role in the establishment and persistence of mycoplasma infections by enabling evasion of host defenses and by ensuring adaptation to the rapidly changing microenvironmental conditions encountered in the host [xxxi]. Nonspecific interactions between mycoplasmas and B-lymphocytes have been implicated in disease pathogenesis, possibly leading to autoimmune reactions, modulation of immunity, and/or promotion of lesion development [xxxii]. The potential role of mycoplasmas in various joint diseases remains unknown but they could be an important factor or cofactor. Thus the complex relationship between mycoplasmal infections and the immune system of the host may be, in part, responsible for the pathogenesis of rheumatological inflammatory diseases. For example, *M. arthritidis*-related superantigens were found to compromise T-cells [xxxiii], and they can trigger and exacerbate autoimmune arthritis in animal models. Furthermore, this mycoplasma species releases substances that act on polymorphnuclear granulocytes, such as oxygen radicals, and chemotactic and aggregating substances [xxxiv]. Several studies have shown that mycoplasmal infections lead to increased levels of proinflammatory cytokines, such Interleukin-1, -2, -4 and -6 [xxxv, xxxvi]. Therefore, *M. arthritidis* and possibly other species may be responsible, in part, for autoimmune phenomena at the early stages of RA, and in their progression. Deficient or aberrant immune responses (or other underlying diseases) might be necessary for the development and progression of RA and other rheumatological illnesses.

Other microorganisms are still under investigation as causative agents or important cofactors for these chronic diseases. Reports about the detection of Epstein-Barr virus or cytomegalovirus in synovial specimen are controversial [xxxvii, xxxviii, xxxix]. Furthermore, retroviruses and enteropathogenic bacteria continue to be intensively discussed as possible etiologic factors of RA [xl, xli]. The identification of mycoplasmal infections in the leukocyte blood fractions of a rather large subset of RA patients support the hypothesis that mycoplasmas, and probably other chronic infections as well, may be an important source or cofactor for morbidity in these patients. Further investigation of the potential role of mycoplasma in RA patients will require comparison with other forms of arthritis and chronic inflammatory diseases.

Recently, it was found that minocycline is an interesting new drug for the treatment of RA. Tetracycline compounds have long been used by rheumatologists, and their antirheumatic activity has been demonstrated [xlii]. The reason why minocycline alleviates the clinical signs and symptoms of RA is unclear, but the responses of some patients with RA to minocycline might be due to the susceptibility of mycoplasmas to tetracyclines [xliii].

Table 1.

Sequences from mycoplasmal DNA used for mycoplasma genus -specific and species-specific PCR. Specificity of each primer was evaluated using Blast-Search program on the GenBank [xliv].

Sequence name	Sequence	Target	Size [bp]	Source
GPO1 primer MGSO primer UNI- probe	**ACT CCT ACG GGA GGC AGC AGT A** **TGC ACC ATC TGT CAC TCT GTT AAC CTC** **TAA TCC TGT TTG CTC CCC AC**	16S mRNA Genus	717	Van Kuppeveld 1992 [xxiv]
SB 1 primer SB 2 primer SB 3 probe	**CAG TAT TAT CAA AGA AGG GTC TT** **TCT TTG GTT ACG TAA ATT GCT** **TTT TTC AGT TTC GTA TTC GAT G**	*tuf* gene *M. fermentans*	850	Berg 1995 [xxiii]
MP5-1 primer MP5-2 primer MP5-4 probe	**GAA GCT TAT GGT ACA GGT TGG** **ATT ACC ATC CTT GTT GTA AGG** **CGT AAG CTA TCA GCT ACA TGG AGG**	*unknown gene* *M. pneumoniae*	144	Bernet 1989 [xlv]
Mhom1 primer Mhom2 primer GPO1 probe	**TGA AAG GCG CTG TAA GGC GC** **GTC TGC AAT CAT TTC CTA TTG CAA A** **ACT CCT ACG GGA GGC AGC AGT A**	16S mRNA *M. hominis*	281	Van Kuppeveld 1992 [xxiv]
IMM-7 primer IMM-5 primer IMM-3 probe	**GGA AAC GGG AAT GGT GGA ACA GAT** **TTC TGC TAA TGT TAC AGC AGC AGG** **AGG GAA TCT GTG ATC TTA TTC**	P35 gene (Lipoprotein) *M. penetrans*	704	Nasralla 1998 [xlvi]

References
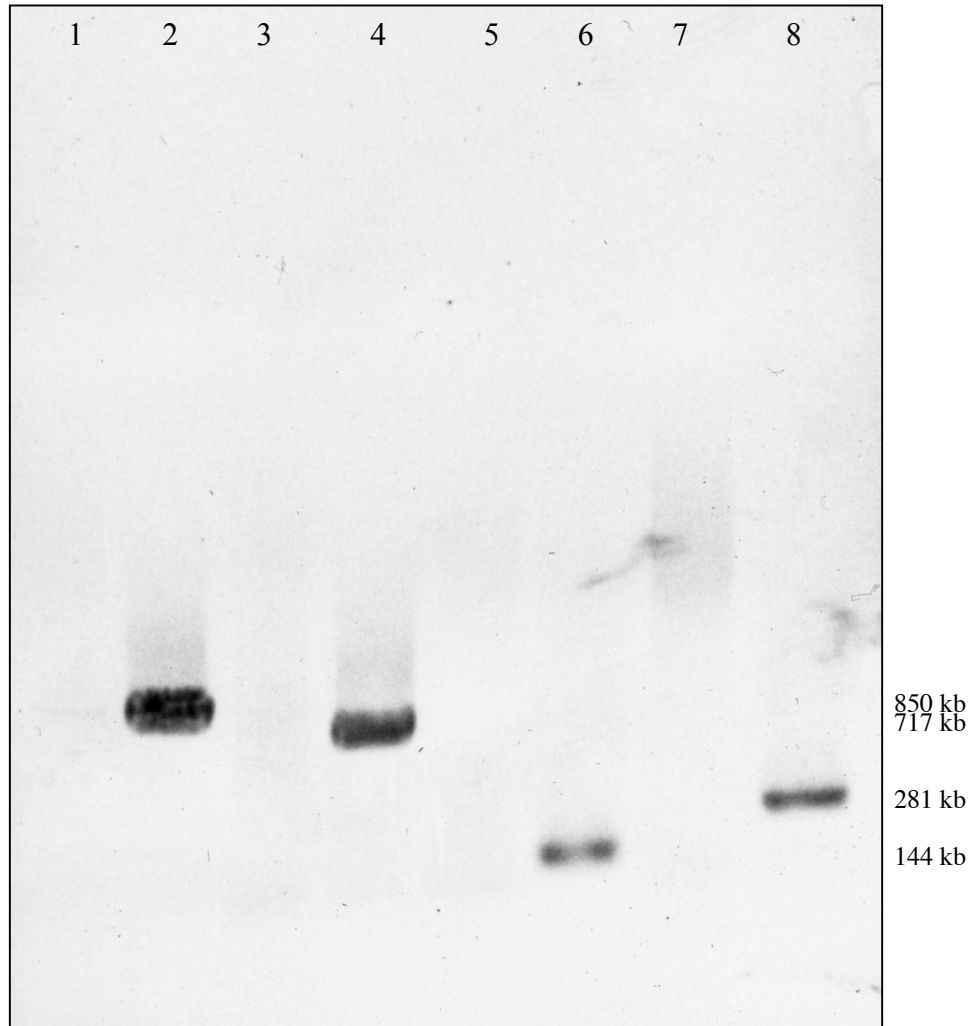
1. Razin S. Molecular biology and genetics of mycoplasmas (Mollicutes). Microbiol. Rev. 1985; 49: 419-455.

2. Razin S, Freundt EA. The Mycoplasmas. In Krieg NR and Holt JG (editors), Bergey's Manual of Systematic Bacteriology, vol. 1. Baltimore. Williams and Wilkins, Co.; 1984, p. 740-93

3. Baseman JB, Tully JG. Mycoplasmas: Sophisticated, Reemerging, and Burdened by Their Notoriety. Emerg. Infect. Dis. 1997; 3: 21-32

4. Rawadi FA, Roman S, Castredo M, et al. Effects of Mycoplasma fermentans on the myelomonocytic lineage. J. Immunol. 1996; 156: 670-680.

5. Balassanian N, Robbins FC. Mycoplasma pneumoniae infection in families. N. Engl. J. Med. 1967; 277: 719.

6. Fernald G W, CollierAM, Clyde Jr WA. Respiratory infection due to Mycoplasma pneumoniae in infants and children. Pediatrics 1975; 55: 327-335.

7. Furr PM, Taylor-Robinson D, Webster ADB. Mycoplasmas and ureaplasmas in patients with hypogamaglobulinemia and their roll in arthritis: microbiological observation over twenty years. Ann. Rheum. Dis. 1994; 53: 183-187.

8. Hoffman RW, O'Sullivan FX, Schafermeyer KR et al. Mycoplasma infection and rheumatoid arthritis: analysis of their relationship using immunoblotting and an ultrasensitive polymerase chain reaction detection method. Arthritis Rheum. 1997; 40: 1219-1228

9.   Lee AH, Levinson AI, Schumacher HR Jr. Hypogammaglobulinemia and rheumatic disease. Semin. Arthritis Rheum. 1993; 22: 252-264

10. Clark HW, Coker-Vann MR, Bailey JS, Brown TM. Detection of mycoplasmal antigens in immune system complexes from rheumatoid arthritis synovial fluids. Ann. Allergy, 1988; 60: 394-398

11. Nicolson GL. Nasralla M, Haier J, Nicolson NL. Diagnosis and treatment of chronic mycoplasmal infections in fibromyalgia and chronic fatigue syndromes: Relationship to gulf war illness. Biomedical Therapy, 1998; 16: 266-271

12. Nicolson GL, Nicolson NL, Nasralla M. Mycoplasma infections and Chronic Fatigue Illness (Gulf War Illness) associated with deployment to Operation Desert storm. Intern. J. Med. 1998; 1: 80-92.

13. Nicolson GL, Nicolson NL. Diagnosis and treatment of mycoplasmal infections in Persian Gulf War Illness-CFIDS patients. Int. J. Occup. Med. Tox .1996; 5: 69-78.

14. Cimolai N, Malleson P, Thomas E, Middleton PJ. Mycoplasma pneumoniae associated arthropathy: confirmation of the association by determination of the antipolypeptide IgM response. J. Rheumatol. 1989; 16: 1150-1152

15. Barile MF, Yoshida H, Roth H. Rheumatoid arthritis: new findings on the failure to isolate or detect mycoplasmas by multiple cultivation or serological procedures and a review ot the literature. Rev. Infect. Dis. 1991; 13: 571-582

16. Stephenson J. Studies suggest a darker side of 'benign' microbes. JAMA 1997; 278: 2051-2052

17. Schaeverbeke T, Gilroy CB, Bebear C, Dehais J, Taylor-Robinson D. Mycoplasma fermentans, but not M. penetrans, detected by PCR assays in synovium from patients with rheumatoid arthritis and other rheumatic disorders. J. Clin. Pathol. 1996; 49: 824-828

18. Taylor-Robinson D, Gilroy CB, Horowitz S, Horowitz J. Mycoplasma genitalium in the joints of two patients with arthritis. Eur. J. Clin. Microbiol. Infect. Dis. 1994; 13: 1066-1069

19. Schaeverbeke T, Renaudin H, Clerc M et al. Systematic detection of mycoplasmas by culture and polymerase chain reaction (PCR) procedures in 209 synovial fluid samples. Br. J. Rheumatol. 1997; 36: 310-314

20. Hochberg MC, Chang RW, Dwosh I, Lindsey S, Pincus T, Wolfe F. The American College of Rheumatology 1991 revised criteria for the classification of global functional status in rheumatoid arthritis. Arthritis Rheum. 1992, 35: 498-502

21. Erlich, HA, Gelfand D, Sninsky JJ. Recent advances in the polymerase chain reaction. Science 1991; 252:1643-1651

22. Kwok S, Higuchi. R. Avoiding false positive with PCR. Nature (London) 1989;339:237-238

23. Berg S, Lueneberg E, Frosch M. Development of an amplification and hybridization assay for the specific and sensitive detection of Mycoplasma fermentans DNA. Mol. Cell. Probes 1996; 10: 7-14

24. Van Kuppeveld, FJM, Van der logt JTM, Angulo AF et al. Genus- and species-specific identification of mycoplasmas by 16S rRNA amplification. Appl. Environ. Microbiol. 1992;58:2606-2615.

25. Dussurget O, Roulland-Dussoix D. Rapid, sensitive PCR-based detection od mycoplasmas in simulated samples of animal sera. Appl. Environ. Microbiol. 1994; 60: 953-959

26. Midtvedt T. Intestinal bacteria and rheumatic disease. Scan. J. Rheumatol. Suppl. 1987; 64: 49-54

27. Schaeverbeke T, Vernhes JP, Lequen L, Bannwarth B, Bebear C, Dehais J. Mycoplasmas and arthritides. Rev. Rheum. Engl. Ed. 1997; 64: 120-128

28. Prattichizzo FA, Simonetti I, Galetta F. Carditis associated with Mycoplasma pneumoniae infection. Clinical aspects and therapeutic problems. Minerva Cardioangiol. 1997; 45: 447-50

29. O'Connor CM, Campbell PT, Van Trigt P, Corey GR. Mycoplasmal pericarditis: evidence of invasive disease. Clin. Infect. Dis. 1993; 17 (Suppl. 1): S58-62

30. Kumada S, Kusaka H, Okaniwa M, Kobayashi O, Kusunoki S. Encephalomyelitis subsequent to mycoplasma infection with elevated serum anti-Gal C antibody. Pediatr. Neurol. 1997; 16: 241-4

31. Citti C, Rosengarten R. Mycoplasma genetic variation and its implication for pathogenesis. Wien. Klin. Wochenschr. 1997; 109: 562-8

32. Simecka JW, Ross SE, Cassell GH, Davis JK. Interactions of mycoplasmas with B cells: antibody production and nonspecific effects. Clin. Infect. Dis. 1993; 17 (Suppl. 1): S176-82

33. Cole BC, Griffith MM. Triggering and exacerbation of autoimmune arthritis by the Mycoplasma arthritidis superantigen MAM. Arthitis Rheum. 1993; 36: 994-1002

34. Kirchhoff H, Binder A, Runge M, Meier B, Jacobs R, Busche K. Pathogenic mechanisms in the Mycoplasma arthritidis polyarthritis of rats. Rheumatol. Int. 1989; 9: 193-196

35. Mühlradt PF, Quentmeier H, Schmitt E. Involvement of interleukin-1 (IL-1), IL-6, IL-2 and IL-4 in generation of cytolytic T cells from thymocytes stimulated by a Mycoplasma fermentans-derived product. Infect. Immun. 1991; 59: 3962-3968

36. Quentmeier H, Schmitt E, Kirchhoff H, Grote W, Mühlradt PF. Mycoplasma fermentans-derived high-molecular weight material induces interleukin-6 release in cultures of murine macrophages and human monocytes. Infect. Immun. 1990; 58: 1273-1280

37. Fox RI, Luppi M, Pisa P, Kang HI. Potential role of Epstein-Barr virus in Sjögren's syndrome and rheumatoid arthritis. J. Rheumatol. Suppl. 1992; 32: 18-24

38. Takei M, Mitamura K, Fujiwara S, Horie T, Ryu J, Osaka S, Yoshino S, Sawada S. Detection of Epstein-Barr virus-encoded small RNA 1 and latent membrane protein 1 in synovial lining cells from rheumatoid arthritis patients. Int. Immunol. 1997; 9: 739-43

39. Tsai YT, Chiang BL, Kao YF, Hsieh KH. Detection of Epstein-Barr virus and cytomegalovirus genome in white blood cells from patients with juvenile rheumatoid arthritis and childhood systemic lupus erythematosus. Int. Arch. Allergy Immunol. 1995; 106: 235-40

40. Aoki S, Yoshikawa K, Yokoyama T, Nonogaki T, Iwasaki S, Mitsui T, Niwa S. Role of enteric bacteria in the pathogenesis of rheumatoid arthritis: evidence for antibodies to enterobacterial common antigens in rheumatoid sera and synovial fluids. Ann. Rheum. Dis. 1996; 55: 363-9

41. Krause A, Kamradt T, Burmester GR. Potential infectious agents in the induction of arthritides. Curr. Opin. Rheumatol. 1996; 8: 203-9

42. Trentham DE, Dynesius Trentham RA. Antibiotic therapy for rheumatoid arthritis. Scientific and anecdotal appraisals. Rheum. Dis. Clin. North Am. 1995; 21: 817-834

43. Tilley BC, Alarcon GS, Heyse SP, et al. Minocycline in rheumatoid arthritis. A 48-week, double-blind, placebo-controlled trial. MIRA Trial Group. Ann. Intern. Med. 1995; 122: 81-89

44. Altshul SF, Gish W, Miller W, Myers EW, Lipman DJ. Basic local alignment search tool. J. Mol. Biol. 1990; 215: 403-410

45. Bernet C, Garret M, de Barbeyrac B, Bebear C, Bonnet J. Detection of Mycoplasma pneumoniae by using the polymerase chain reaction. J. Clin. Microbiology 1989; 27: 2492-2496

46. Nasralla M, Haier J, Nicolson GL. Specific Polymerase Chain Reaction for the detection of Mycoplasma penetrans by amplification of a specific sequence in the lipoprotein Gene. submitted

Figure 1. Detection of different mycoplasma species in control samples. Each sample was prepared as a positive control containing species-specific DNA and a negative control containing water. Control DNA were detected using primer pairs as described in table 1. Electrophoresis was carried out on agarose-gel containing ethidium bromide. Bands were visualized using UV light. Lane 1: *M. fermentans* (negative control); Lane 2: *M. fermentans* (positive control); Lane 3: *M. penetrans* (negative control); Lane 4: *M. penetrans* (positive control); Lane 5: *M. pneumoniae* (negative control); Lane 6: *M. pneumoniae* (positive control); Lane 7: *M. hominis* (negative control); Lane 8: *M. hominis* (positive control). Inverted figure.

i Razin S. Molecular biology and genetics of mycoplasmas (Mollicutes). Microbiol. Rev. 1985; 49: 419-455.

ii Razin S, Freundt EA. The Mycoplasmas. In Krieg NR and Holt JG (editors), Bergey's Manual of Systematic Bacteriology, vol. 1. Baltimore. Williams and Wilkins, Co.; 1984, p. 740-93

iii Baseman JB, Tully JG. Mycoplasmas: Sophisticated, Reemerging, and Burdened by Their Notoriety. Emerg. Infect. Dis. 1997; 3: 21-32

iv Rawadi FA, Roman S, Castredo M, et al. Effects of Mycoplasma fermentans on the myelomonocytic lineage. J. Immunol. 1996; 156: 670-680.

v Balassanian N, Robbins FC. Mycoplasma pneumoniae infection in families. N. Engl. J. Med. 1967; 277: 719.

vi Fernald G W, CollierAM, Clyde Jr WA. Respiratory infection due to Mycoplasma pneumoniae in infants and children. Pediatrics 1975; 55: 327-335.

vii Furr PM, Taylor-Robinson D, Webster ADB. Mycoplasmas and ureaplasmas in patients with hypogamaglobulinemia and their roll in arthritis: microbiological observation over twenty years. Ann. Rheum. Dis. 1994; 53: 183-187.

viii Hoffman RW, O'Sullivan FX, Schafermeyer KR et al. Mycoplasma infection and rheumatoid arthritis: analysis of their relationship using immunoblotting and an ultrasensitive polymerase chain reaction detection method. Arthritis Rheum. 1997; 40: 1219-1228

ix Lee AH, Levinson AI, Schumacher HR Jr. Hypogammaglobulinemia and rheumatic disease. Semin. Arthritis Rheum. 1993; 22: 252-264

x Clark HW, Coker-Vann MR, Bailey JS, Brown TM. Detection of mycoplasmal antigens in immune system complexes from rheumatoid arthritis synovial fluids. Ann. Allergy, 1988; 60: 394-398

xi Nicolson GL. Nasralla M, Haier J, Nicolson NL. Diagnosis and treatment of chronic mycoplasmal infections in fibromyalgia and chronic fatigue syndromes: Relationship to gulf war illness. Biomedical Therapy, 1998; 16: 266-271

xii Nicolson GL, Nicolson NL, Nasralla M. Mycoplasma infections and Chronic Fatigue Illness (Gulf War Illness) associated with deployment to Operation Desert storm. Intern. J. Med. 1998; 1: 80-92.

xiii Nicolson GL, Nicolson NL. Diagnosis and treatment of mycoplasmal infections in Persian Gulf War Illness-CFIDS patients. Int. J. Occup. Med. Tox .1996; 5: 69-78.

xiv Cimolai N, Malleson P, Thomas E, Middleton PJ. Mycoplasma pneumoniae associated arthropathy: confirmation of the association by determination of the antipolypeptide IgM response. J. Rheumatol. 1989; 16: 1150-1152

xv Barile MF, Yoshida H, Roth H. Rheumatoid arthritis: new findings on the failure to isolate or detect mycoplasmas by multiple cultivation or serological procedures and a review ot the literature. Rev. Infect. Dis. 1991; 13: 571-582

xvi Stephenson J. Studies suggest a darker side of 'benign' microbes. JAMA 1997; 278: 2051-2052

xvii Schaeverbeke T, Gilroy CB, Bebear C, Dehais J, Taylor-Robinson D. Mycoplasma fermentans, but not M. penetrans, detected by PCR assays in synovium from patients with rheumatoid arthritis and other rheumatic disorders. J. Clin. Pathol. 1996; 49: 824-828

xviii Taylor-Robinson D, Gilroy CB, Horowitz S, Horowitz J. Mycoplasma genitalium in the joints of two patients with arthritis. Eur. J. Clin. Microbiol. Infect. Dis. 1994; 13: 1066-1069

xix Schaeverbeke T, Renaudin H, Clerc M et al. Systematic detection of mycoplasmas by culture and polymerase chain reaction (PCR) procedures in 209 synovial fluid samples. Br. J. Rheumatol. 1997; 36: 310-314

xx Hochberg MC, Chang RW, Dwosh I, Lindsey S, Pincus T, Wolfe F. The American College of Rheumatology 1991 revised criteria for the classification of global functional status in rheumatoid   arthritis. Arthritis Rheum. 1992, 35: 498-502

xxi Erlich, HA, Gelfand D, Sninsky JJ. Recent advances in the polymerase chain reaction. Science 1991; 252:1643-1651

xxii Kwok S, Higuchi. R. Avoiding false positive with PCR. Nature (London) 1989;339:237-238

xxiii Berg S, Lueneberg E, Frosch M. Development of an amplification and hybridization assay for the specific and sensitive detection of Mycoplasma fermentans DNA. Mol. Cell. Probes 1996; 10: 7-14

xxiv Van Kuppeveld, FJM, Van der logt JTM, Angulo AF et al. Genus- and species-specific identification of mycoplasmas by 16S rRNA amplification. Appl. Environ. Microbiol. 1992;58:2606-2615.

xxv Dussurget O, Roulland-Dussoix D. Rapid, sensitive PCR-based detection od mycoplasmas in simulated samples of animal sera. Appl. Environ. Microbiol. 1994; 60: 953-959

xxvi Midtvedt T. Intestinal bacteria and rheumatic disease. Scan. J. Rheumatol. Suppl. 1987; 64: 49-54

xxvii Schaeverbeke T, Vernhes JP, Lequen L, Bannwarth B, Bebear C, Dehais J. Mycoplasmas and arthritides. Rev. Rheum. Engl. Ed. 1997; 64: 120-128

xxviii Prattichizzo FA, Simonetti I, Galetta F. Carditis associated with Mycoplasma pneumoniae infection. Clinical aspects and therapeutic problems. Minerva Cardioangiol. 1997; 45: 447-50

xxix O'Connor CM, Campbell PT, Van Trigt P, Corey GR. Mycoplasmal pericarditis: evidence of invasive disease. Clin. Infect. Dis. 1993; 17 (Suppl. 1): S58-62

xxx Kumada S, Kusaka H, Okaniwa M, Kobayashi O, Kusunoki S. Encephalomyelitis subsequent to mycoplasma infection with elevated serum anti-Gal C antibody. Pediatr. Neurol. 1997; 16: 241-4

xxxi Citti C, Rosengarten R. Mycoplasma genetic variation and its implication for pathogenesis. Wien. Klin. Wochenschr. 1997; 109: 562-8

xxxii Simecka JW, Ross SE, Cassell GH, Davis JK. Interactions of mycoplasmas with B cells: antibody production and nonspecific effects. Clin. Infect. Dis. 1993; 17 (Suppl. 1): S176-82

xxxiii Cole BC, Griffith MM. Triggering and exacerbation of autoimmune arthritis by the Mycoplasma arthritidis superantigen MAM. Arthitis Rheum. 1993; 36: 994-1002

xxxiv Kirchhoff H, Binder A, Runge M, Meier B, Jacobs R, Busche K. Pathogenic mechanisms in the Mycoplasma arthritidis polyarthritis of rats. Rheumatol. Int. 1989; 9: 193-196

xxxv Mühlradt PF, Quentmeier H, Schmitt E. Involvement of interleukin-1 (IL-1), IL-6, IL-2 and IL-4 in generation of cytolytic T cells from thymocytes stimulated by a Mycoplasma fermentans-derived product. Infect. Immun. 1991; 59: 3962-3968

xxxvi Quentmeier H, Schmitt E, Kirchhoff H, Grote W, Mühlradt PF. Mycoplasma fermentans-derived high-molecular weight material induces interleukin-6 release in cultures of murine macrophages and human monocytes. Infect. Immun. 1990; 58: 1273-1280

xxxvii Fox RI, Luppi M, Pisa P, Kang HI. Potential role of Epstein-Barr virus in Sjögren's syndrome and rheumatoid arthritis. J. Rheumatol. Suppl. 1992; 32: 18-24

xxxviii Takei M, Mitamura K, Fujiwara S, Horie T, Ryu J, Osaka S, Yoshino S, Sawada S. Detection of Epstein-Barr virus-encoded small RNA 1 and latent membrane protein 1 in synovial lining cells from rheumatoid arthritis patients. Int. Immunol. 1997; 9: 739-43

xxxix Tsai YT, Chiang BL, Kao YF, Hsieh KH. Detection of Epstein-Barr virus and cytomegalovirus genome in white blood cells from patients with juvenile rheumatoid arthritis and childhood systemic lupus erythematosus. Int. Arch. Allergy Immunol. 1995; 106: 235-40

xl Aoki S, Yoshikawa K, Yokoyama T, Nonogaki T, Iwasaki S, Mitsui T, Niwa S. Role of enteric bacteria in the pathogenesis of rheumatoid arthritis: evidence for antibodies to enterobacterial common antigens in rheumatoid sera and synovial fluids. Ann. Rheum. Dis. 1996; 55: 363-9

xli Krause A, Kamradt T, Burmester GR. Potential infectious agents in the induction of arthritides. Curr. Opin. Rheumatol. 1996; 8: 203-9

xlii Trentham DE, Dynesius Trentham RA. Antibiotic therapy for rheumatoid arthritis. Scientific and anecdotal appraisals. Rheum. Dis. Clin. North Am. 1995; 21: 817-834

xliii Tilley BC, Alarcon GS, Heyse SP, et al. Minocycline in rheumatoid arthritis. A 48-week, double-blind, placebo-controlled trial. MIRA Trial Group. Ann. Intern. Med. 1995; 122: 81-89

xliv Altshul SF, Gish W, Miller W, Myers EW, Lipman DJ. Basic local alignment search tool. J. Mol. Biol. 1990; 215: 403-410

xlv Bernet C, Garret M, de Barbeyrac B, Bebear C, Bonnet J. Detection of Mycoplasma pneumoniae by using the polymerase chain reaction. J. Clin. Microbiology 1989; 27: 2492-2496

xlvi Nasralla M, Haier J, Nicolson GL. Specific Polymerase Chain Reaction for the detection of Mycoplasma penetrans by amplification of a specific sequence in the lipoprotein Gene. submitted