Serological characterisation of *Ureaplasma urealyticum* strains by enzyme-linked immunosorbent assay (ELISA)

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**SUMMARY** A modification of enzyme-linked immunosorbent assay (ELISA) was developed for the serological characterisation and identification of strains of *Ureaplasma urealyticum*. The eight recognised human serotypes of *U urealyticum* and antisera produced against them were used as reference for the evaluation and standardisation of the method. The serological profile illustrating reactions of antigen with homologous and heterologous antisera was specific and reproducible for each serotype. The homologous reaction was always very prominent but some cross-reactivity was seen, most clearly between serotypes 2 and 5. The method was found to be suitable for serological typing of clinical isolates of *U urealyticum* because of rapid and simple technical procedure, good reproducibility of the results and economical consumption of antisera and other reagents.

The serological typing of clinical isolates of *Ureaplasma urealyticum* may be an important approach in establishing the aetiological role of *U urealyticum* in pathological conditions of man. Tests used so far have limitations due to complex technical procedures and difficulties in standardisation of the test results. At least eight serotypes have been reported by methods such as growth inhibition, metabolic inhibition, and indirect immunofluorescence. By using a mycoplasmacidal test, Ureaplasma strains have been divided further and recent studies have indicated that as many as 15 serotypes may exist.

We have developed ELISA for various immunological studies in our laboratory and describe here an application which can be used for serological characterisation of Ureaplasma strains isolated from patients. It is technically simple and seems to give a characteristic serological profile for the different serotypes. As the reference in our study we used eight Ureaplasma serotypes and the corresponding antisera as described by Black.

**Material and methods**

**ORGANISMS**
Reference strains of the eight recognised serotypes of *Ureaplasma urealyticum* were obtained in lyophilised form from Dr MC Shepard, Naval Regional Medical Centre, Camp Lejeune, North Carolina, USA. Clinical strains were isolated from urethral specimens of male and female patients with urethritis and arthritis.

**CULTURE MEDIA**
Standard fluid medium 10-B was used for primary cultivation of the type strains and the urethral specimens. Subcultures were done on differential agar medium A-7. Fluid medium U-9, supplemented with L-cysteine hydrochloride to a final concentration 0-01% (U-9B), was used for the production of antigens for the ELISA test.

**PREPARATION OF ANTIGENS**
Antigens from the reference strains were prepared by inoculating a three-litre volume of U-9B medium with 30 ml of an overnight culture of each strain. The cultures were incubated at +37°C for 18-20 hr. The organisms were harvested by centrifugation in a Sorvall RC-5 centrifuge at 15 000 rpm for 60 min. The pellets were resuspended in phosphate-buffered saline (PBS) pH 7-2 and pooled, washed twice with PBS and finally resuspended in 30 ml of PBS. The suspension was sonicated with a MSE sonicator for one minute and stored at −70°C in 1 ml aliquots.

Antigens from clinical isolates were prepared by using a modified U-9B medium, supplemented with 5% (vol/vol) newborn calf serum instead of normal horse serum. A 0-5 ml volume of the primary culture...
was inoculated into 30 ml volume of modified U-9B medium and after incubation at +37°C for 18-20 hr the organisms were collected by centrifugation in a Sorvall RC-5 centrifuge at 15000 rpm for 30 min. Without further washing the pellet was resuspended in 15 ml of carbonate-bicarbonate buffer pH 9-6 sonicated and used for sensitising polystyrene cuvettes.

PREPARATION OF ANTISERA

Two albino rabbits (3 kg) were used for immunisation with each of the eight type strains. For primary immunisation 1 ml of antigen (0·5 mg of protein) emulsified with equal volume of complete Freund adjuvant was injected subcutaneously into each rabbit at four different sites. After 14 days each rabbit received a booster of 0·5 ml of antigen (0·25 mg of protein) intravenously. After 10 days animals were exsanguinated. Sera were stored at −20°C.

ELISA METHOD

Tests were carried out in disposable polystyrene nine-microcuvette blocks (Finnpipette-Labsystems Oy, Helsinki, Finland). All antigens were diluted in carbonate-bicarbonate buffer pH 9-6. Amounts (250 μl) of diluted antigen were added to each cuvette and incubated overnight at +37°C. After incubation they were washed three times with PBS pH 7-2 containing 0·5% (vol/vol) Tween 20 and rinsed with distilled water.

Antisera were diluted in PBS containing 1% (wt/vol) bovine serum albumin, 0·05% (vol/vol) Tween-20 and 10% (vol/vol) normal horse serum. Portions (200 μl) of diluted antiserum was incubated in each cuvette at +37°C for 60 min. The washing procedure was as before.

Alkaline phosphatase conjugated antirabbit IgG (Orion Diagnostica Oy, Helsinki, Finland) was used as a conjugate: 200 μl, diluted in PBS with 1% (wt/vol) bovine serum albumin and 0·05% (vol/vol) Tween-20 was incubated at +37°C for 90 min.

After washing, 200 μl of p-nitrophenylphosphate (Sigma Co, St Louis, USA), 1 mg/ml, diluted in diethanolamine-MgCl₂-buffer pH 10-0 (Orion Diagnostica Oy, Helsinki, Finland) was incubated at +37°C for 30 min and the reaction stopped by adding 400 μl of 0·15 M NaOH.

The optical absorbances were measured through the bottoms of the cuvettes with a specially designed nine-channel spectrophotometer (FP-9, Labsystems Oy, Helsinki, Finland) at a wavelength of 405 nm. Three parallel determinations for each antiserum were run and the arithmetic mean value was used to calculate the ratios between heterologous and homologous reactions.

Results

The reference serotype 8, Ureaplasma strain 960-(CX8), was used to study the optimal conditions for the test procedure.

ANTIGEN CONCENTRATION

Solutions of different antigen concentrations were used to sensitise the polystyrene cuvettes. The homologous serotype 8 antiserum, and the heterologous serotype 6 antiserum were used in ELISA to characterise the sensitised cuvettes. The results are presented in Fig. 1. There is an almost linear correlation between the uptake of serotype 8 antiserum and the antigen concentration within the range from 6 μg/ml to 0·6 μg/ml of antigen protein. The best specificity was obtained at a concentration of 2 μg/ml. The linearity was lost and the specificity decreased at higher and lower dilutions of antigen.

![Fig. 1 Absorbance curves for homologous serotype 8 antiserum (●) and heterologous serotype 6 antiserum (○-○) tested with Ureaplasma serotype 8 antigen at different antigen concentrations.](image-url)


Serological characterisation of Ureaplasma urealyticum strains

SEROLOGICAL CHARACTERISATION OF STAINOS OF Ureaplasma urealyticum

SERUM DILUTION

Optimal serum dilutions were determined by testing serial dilutions from $10^{-1}$ to $10^{-5}$. The optimal difference between homologous and heterologous antiserum was obtained at the serum dilution $10^{-3}$ (Fig. 3). The linear part of the curve for the homologous antiserum was obtained at the serum dilutions from $10^{-2}$ to $10^{-4}$. A slight prozone effect was observed at low serum dilutions (data not shown).

![Graph](image1)

**Abs** of horse serum (v/v)%

**Conc** of horse serum (v/v)%

**Fig. 2** Effect of normal horse serum added into the antiserum diluent. Absorbance values for homologous serotype 8 antiserum (●-●) and heterologous serotype 6 antiserum (○-○) tested with Ureaplasma serotype 8 antigen.

![Graph](image2)

**Abs** vs Serum dilution

**Fig. 3** Absorbance curves for homologous serotype 8 antiserum (●-●) and heterologous serotype 6 antiserum (○-○) tested in serial dilutions from $10^{-1}$ to $10^{-5}$ with Ureaplasma serotype 8 antigen.

REPRODUCIBILITY OF TEST RESULTS

Serotype 8 antigen was tested in five independent tests performed on different days by using the homologous and two heterologous antisera, antisera 7 and 3. The results are shown in the Table. The results are expressed as the ratio of absorbance readings of heterologous v homologous reaction. This ratio for antiserum 7 varied between 0.24 to 0.30 and the calculated interassay variation was 6%. For antiserum 3 the ratio was between 0.04 to 0.06 with interassay variation of 2%.

![Table](image3)

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SEROLOGICAL CHARACTERISATION OF REFERENCE STRAINS OF Ureaplasma urealyticum BY ELISA

The serological profiles of the eight reference strains as characterised by homologous and heterologous antisera are presented in Fig. 4.

The height of each column represents the ratio between absorbance readings of each heterologous antiserum and the homologous antiserum. The serological profiles were found to be completely reproducible and characteristic for each individual serotype.

The homologous reaction was always very prominent when compared with heterologous reactions. For example serotype 1 antigen gave a distinctive reaction with type 1 antiserum and only minimal cross-reactivity with heterologous antisera. Serotype 2 antigen also gave a prominent homologous reaction but in addition a clearcut cross-reaction with type 5 antiserum. A “reverse” pattern was observed with serotype 5 antigen which reacted also with type 2 antiserum. Serotype 8 antiserum reacted significantly also with type 4 and, to a lesser extent, also with type 7 antigens.

SEROLOGICAL CHARACTERISATION OF CLINICAL ISOLATES

Clinical isolates from patients with urethritis and arthritis were studied by using the same antisera
Discussion

*Ureaplasma urealyticum* was first isolated from the urethral discharge of a man suffering from nongonococcal urethritis (NGU) and since then ureaplasmas have been studied both in this disorder and related infections. Results of isolation studies have been conflicting but recent studies based on the use of differential antibiotics and on the inoculation of human volunteers have proved *Ureaplasma urealyticum* to be a human pathogen and a cause of urethritis. Ureaplasmas can also be isolated from apparently healthy subjects which may reflect differences in the pathogenicity of various strains.

The human Ureaplasmas form a serologically heterogeneous group consisting of at least eight different serotypes. Clinical isolates have been serologically typed to find out whether a particular serotype is associated with the disease. No such association has been found regularly but the number of types isolated is still relatively small. Shepard and Lunceford tested 338 strains of *Ureaplasma urealyticum* by using a modified growth inhibition method. Serotype 4 was most frequently associated with NGU and some other disorders of the genitourinary tract.

The methods for serotyping have certain limitations. The growth inhibition test is highly specific but quite insensitive and requires large volumes of potent antisera. The metabolic inhibition test is sensitive but growing organisms are used, as in the growth inhibition test, and a careful arrangement of test conditions is necessary. The indirect immunofluorescence test is sensitive and quite specific but the interpretation of results is liable to be inaccurate and variable because the intensity of fluorescence is estimated microscopically by subjective criteria.

The ideal method for serotyping strains of *Ureaplasma urealyticum* should have a high specificity and sensitivity with economical consumption of antisera and other reagents. The method should also be rapid and simple in order to be suitable for typing of large numbers of isolates. The reproducibility of the results should be good and reliable. Our application of ELISA seems to meet most of these demands.

Because of the high sensitivity only 30 ml of Ureaplasma culture is needed for the preparation of the antigen to be characterised. The consumption of antisera is also low: 10 μl of each antiserum is required for one complete test. The consumption of enzyme-conjugated antirabbit immunoglobulin is economical because of the high dilutions that can be used. The measurement of the reactions with a spectrophotometer improves accuracy and objectivity in the final results.

The use of low immunogen doses and a short immunisation period was found to be optimal for

Fig. 4  Serological profiles for eight recognised serotypes of *Ureaplasma urealyticum* as determined by using ELISA. The height of individual columns represents a ratio between absorbance values for heterologous reaction and homologous reaction.

as above. Thirty strains tested showed characteristic profiles indicating their serotypes. Twelve of these isolates showed serological profiles identical with serotype 3 and nine were identical with serotype 6. Two isolates had serological characteristics identical with serotype 1 and another two identical with serotype 4. Serotypes 2, 5 and 8 were represented each by one isolate. Two isolates had profiles indicating a mixture of more than one serotype. One was a mixture of serotypes 2 and 8 and the other of serotypes 1 and 6. This was confirmed by comparing these profiles with profiles from artificial mixtures of the corresponding serotypes.
the production of highly specific antisera as recom-
mended by Kenny. In addition, horse serum
components may contaminate the immunogens
resulting in formation of antibodies against these
proteins. The use of calf serum instead of horse
serum in growth media for typing clinical isolates
eliminates part of this problem. The addition of
horse serum into the antiserum diluent finally makes
the test very specific and sensitive.

In general, the homologous reactions were
prominent when compared to cross-reactions,
demonstrating that antigenic differences between
the strains are clear enough to justify the serological
classification. Nevertheless, some marked cross-
reactions were observed. Serotypes 2 and 5 seemed
to share antigens. This has been noted by other
methods. Also types 4, 7, and 8 possibly share a
common antigenic component. It will be of interest
to see whether new profiles will be seen among
clinical isolates suggesting antigenic compositions
not compatible with the known serotypes.

Mixed cultures of Ureaplasma serotypes in clinical
specimens have been reported. So far our pre-
liminary data suggest that the ELISA method could
also detect these mixed strains in clinical isolates.

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