Antimicrobial susceptibility of *Neisseria gonorrhoeae* in Zaire: high level plasmid-mediated tetracycline resistance in Central Africa

E Van Dyck, R Rossau, M Duhamel, F Behets, M Laga, M Nzila, S Bygdeman, H Van Heuverswijn, P Piot

**Abstract**

**Objective**—To determine the in vitro antimicrobial susceptibility of gonococcal strains isolated in 1988 among female prostitutes in Kinshasa, Zaire and to characterise strains with high level tetracycline resistance.

**Methods**—Minimal inhibitory concentrations of 8 antimicrobials were measured by agar dilution technique. Plasmid profiles and serovars were determined.

**Results**—Two hundred and thirteen strains of *Neisseria gonorrhoeae* were tested of which 59% were β-lactamase producers and an additional 21% showed intermediate or chromosomal resistance to penicillin (MIC = 0.5–8 mg/l). Eleven percent of the strains were resistant to the combination sulfamethoxazole-trimethoprim (MIC > 8 mg/l) and 57% of the isolates showed decreased susceptibility to thiamphenicol (MIC = 1–4 mg/l). All strains were sensitive to spectinomycin, norfloxacin and ceftriaxone and moderately sensitive to kanamycin. Chromosomal resistance to tetracycline was observed in 45% of strains (MIC = 2–8 mg/l). Ten percent were highly resistant to tetracycline (TRNG, MIC = 16–128 mg/l) and were shown to carry a plasmid borne Tet M determinant; such strains were not found in Kinshasa in 1985. TRNG belonged to 4 different serovars, which were also the dominant serovars in non-TRNG.

**Conclusion**—These findings illustrate the high frequency of multiresistant gonococci in Zaire and suggest that high level tetracycline resistant strains of *N. gonorrhoeae* have become endemic in Central Africa.

**Introduction**

Gonorrhoea is a major health problem in Africa and female prostitutes appear an important reservoir of gonococcal infection. Tetracycline is the most widely available antibiotic in many African countries and is still one of the common drugs for treating gonococcal infections. In recent years increased chromosomal resistance to tetracycline (minimal inhibitory concentration (MICs) of 1·0 to 8·0 mg/l) has been found in *Neisseria gonorrhoeae* strains in Africa, and such strains account now for more than 50% of all isolates in some African countries. Plasmid-mediated high level resistance to tetracycline was first observed in *N. gonorrhoeae* (TRNG), (MIC 16–64 mg/l) in 1985 in the US. Since then TRNG strains have also been isolated in Canada, the Netherlands, England and France. Tetra-

cycline resistance in these isolates is due to the presence of a 25·2 megadalton (MDa) conjugative plasmid carrying the Tet M determinant.

We report here on the in vitro susceptibility of 213 *N. gonorrhoeae* strains isolated in Kinshasa, Zaire, to eight antimicrobials. About 10% of these isolates exhibited high level resistance to tetracycline. Plasmid profiles and serovars of these strains were determined.

**Materials and methods**

**Strains and susceptibility testing**

From May to December 1988, 800 female prostitutes were enrolled in a study on the prevalence and incidence of sexually transmitted diseases (STD) in Kinshasa, Zaire. During the study period, a total number of 238 isolates of *N. gonorrhoeae* were obtained using modified Thayer Martin medium. The strains were stored in skimmed milk at −70°C and sent to the Institute of Tropical Medicine, Antwerp, Belgium, where 226 strains (95%) could be recovered. The identification of all strains was confirmed by Gram strain, oxidase reaction and acidification of glucose, but not sucrose, lactose or maltose. The production of β-lactamase was determined by the chromogenic cephalosporin test (Nitrocefin, Oxoid, Basingstoke, UK).

MICs were determined on 213 strains by an agar dilution technique using a Steers replicator. The final bacterial inoculum was 10⁶ colony forming units (CFU). Penicillin, tetracycline, kanamycin and thiamphenicol were provided by the Laboratory of Standards, Ministry of Health, Brussels (Belgium); norfloxacin by Merck Sharp and Dohme (Brussels, Belgium); ceftriaxone, sulfamethoxazole and trimethoprim by Roche (Brussels, Belgium) and spectinomycin by Upjohn (Puurs, Belgium). The antimicrobial combination sulfamethoxazole—trimethoprim (19:1) was tested on Diagnostic Sensitivity Test agar (DST, Oxoid), supplemented with 5% lysed (freezing—thawing) horse blood and 1% Kellogg's supplement. All other antimicrobials were tested on GC agar base (Difco, Detroit, Michigan, USA) with 1% hemoglobin (Difco) and 1% IsoVitalX (BBL,
DNA preparation, DNA fixation and restriction digests

Whole-cell DNA was prepared using a small-scale protocol described below. About one quadrant of the cell-yield of a 90 mm diameter blood agar plate was scraped from the plate and suspended in 500 μl 0-15 M NaCl plus 0-01 M EDTA (pH 8-0) in a 2-5 ml Eppendorf tube. Fifty μl 10% SDS and 25 μl (1 mg/ml) Proteinase K were added and the mixture was incubated at 50°C for 1/2 to 1 h. Five hundred μl phenol/chloroform (1:1) was added and the mixture was rotated for 15 min and centrifuged for 10 min at 13000 rpm. The phenol/chloroform extraction was repeated followed by precipitation of the DNA with two volumes of ethanol for 2 h at -20°C. After pelleting and drying, the DNA was dissolved in 100 μl of 0-01 M Tris Cl pH 7-0 plus 0-001 M EDTA.

The DNA (about 1 μg/spot) was fixed on nitrocellulose membranes (BA85, Schleicher & Schüll, Dassel, FRG) as described previously.12 Restriction enzymes were purchased from Boehringer Mannheim GmbH (Mannheim, FRG) and used as recommended by the suppliers. About 1 μg DNA per digest was used.

Agarose-gelelectrophoresis and Southern blotting

The electrophoresis was done in 0-7% agarose (Type III, Sigma, St Louis, Missouri, USA) gels at approximately 8V/cm for 1 to 3 h in 40 mM Tris Cl pH 7-8, 20 mM NaOAc and 2 mM EDTA. After staining in ethidium bromide (1 mg/ml), Southern blotting to a nitrocellulose membrane (BA85) was performed using a standard protocol.13

Probe synthesis, purification and digoxigenin-labelling

A 24-mer oligonucleotide, with a sequence complementary to a randomly chosen region in the Tet M gene, was chemically synthesised and purified as described earlier.13 Purified oligonucleotide (8 μmol) was labelled using 1 nmol digoxigenin-11-UTTP (Boehringer Mannheim GmbH) and 12-5 units of terminal transferase (Boehringer Mannheim GmbH) in 50 μl 0-1 M sodium cacodylate pH 7-0, 1 mM CoCl2, 0-1 mM dithiothreitol and 50 μg/ml bovine serum albumin for 1/2 h at 37°C. The labelled oligonucleotide was used without further purification.

Hybridisation

The membranes were prehybridised and hybridised following the recommendations provided with the non-radioactive DNA labelling and detection kit (Boehringer Mannheim GmbH) except that 3 X SSC (1 X SSC is: 0-15 M NaCl plus 0-015 M sodium citrate, pH 7-0) instead of 5 X SSC was used. The prehybridisation was performed at 60°C for about 1 h, the hybridisation was done at the same temperature for 3 h using approximately 1 μmol/ml digoxigenin-labelled probe. Subsequently the membranes were washed at 60°C for 30 min in 3 X SSC and for 10 min in 1-5 X SSC at room temperature. The colorimetric detection was performed as recommended by the supplier of the kit mentioned above.

Serological classification

Serological classification into serogroups (W I and W 11/III) and serovars was performed by coagglutination as described by Yam et al14 using reagents with both the Ph set of monoclonal antibodies (Pharmacia Diagnostics AB, Uppsala, Sweden)15 and the GS set of monoclonal antibodies (Syva, Palo Alto, California, USA).17

Results

Antimicrobial susceptibility

Of the 213 N. gonorrhoeae strains tested, 126 (59%) were producing β-lactamase (PPNG) showing MICs for penicillin of 8 to ≥64 μg/ml. Thirty four of the 87 non-PPNG strains had MICs for penicillin of 0-5 to 1 μg/ml and 12 had MICs of ≥2 μg/ml. Thus only 19% of the total number of isolates were sensitive to penicillin. Resistance to tetracycline was also common: 45% of strains had MICs of 2 to 8 μg/ml and 10% were highly resistant showing MICs of 16 to 128 μg/ml. All strains were moderately sensitive to kanamycin. A decreased sensitivity to thiamphenicol was seen in 58% of the isolates (MIC 1-4 μg/ml) and 11% of the strains were resistant to the combination sulfamethoxazole: trimethoprim (19:1) with MICs of more than 8 μg/ml. All of the isolates were susceptible to spectinomycin, norfloxacin and ceftriaxone.

During an earlier survey performed in Kinshasa in 1985, the sensitivities of 93 consecutive isolates of N. gonorrhoeae to six antimicrobials were tested. The results of MIC 50, MIC 90 and MIC ranges for all antimicrobials tested on strains from 1988 and 1985 are shown in table 1. For penicillin the results for non-PPNG strains only are compared. In general the MIC 50 and MIC 90 values of 1988 are equal or one dilution higher than those of 1985. The only important difference between both studies is the sensitivity pattern for tetracycline with a MIC range of 0-5–8 μg/ml in 1985 and of 0-5–128 in 1988.

Twenty one isolates from 1988 were highly resistant to tetracycline (table 2) including 20 strains with a MIC of 16 μg/ml, and 1 strain with a MIC of 128 μg/ml. This latter strain was the only TRNG with a MIC for thiamphenicol of 4 μg/ml, all others showed MICs of 0-25 μg/ml for that antimicrobial while 64% of non-TRNG strains showed decreased susceptibility to thiamphenicol (MICs 1-4 μg/ml).18

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Cockeysville, Maryland, USA). Culture plates containing twofold dilutions of antibiotics were incubated for 24 h at 36°C in a 5% CO2 incubator. The MIC was defined as the lowest concentration of an antimicrobial agent that yielded no growth, no more than 2 colonies or a fine barely visible haze. WHO reference N. gonorrhoeae strains A, B, C, D and E (received from I. Lind, Statens Seruminstitut, Copenhagen, Denmark) were included for each antimicrobial assay.

About 1 μg DNA per digest was used.
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Table 1  Minimum inhibitory concentrations (MICs) of clinical isolates of Neisseria gonorrhoeae from Kinshasa in 1988 (n = 213) and 1985 (n = 93)

<table>
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<th>Antimicrobial</th>
<th>MIC 50 and MIC 90 (mg/liter)</th>
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<tr>
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<td>MIC 50</td>
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<tr>
<td>Tetracycline</td>
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<td>Tiamphenicol</td>
<td>2</td>
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<tr>
<td>Kanamycin</td>
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<td>Spectinomycin</td>
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<td>Kanamycin</td>
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<td>Norfloxacin</td>
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<tr>
<td>Ceftriaxone†</td>
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<td>Sulfamethoxazole/trimethoprim† (19/1)</td>
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TRNG strains (81%) were PPNG, the remaining four strains were sensitive to penicillin (MIC 0.06-0.25 mg/l). Plasmid content

The TRNG isolates were examined for their plasmid content by agarose gel electrophoresis. The plasmid profiles of some representative TRNG are shown in fig 1 (lanes 2 to 5). For comparison plasmid profiles of some non-TRNG strains are also shown (fig 1, lanes 6 to 9). All TRNG strains harboured a large plasmid with an electrophoretic mobility higher than the chromosomal material (fig 1); this is most probably the 25.2 MDa plasmid also identified in TRNG strains by other investigators.4 8 16 19

Among the TRNG isolates three different plasmid profiles (table 2 and fig 1) could be distinguished. Seventeen of the 21 TRNG strains contained a 32 MDa plasmid (lanes 2 and 3 of fig 1) and produced a β-lactamase, with the exception of one strain, (ITM 4451; MIC for penicillin: 0.25 mg/l). Three TRNG strains did not harbour the 32 MDa plasmid (lane 5 of fig 1) and lacked β-lactamase activity. In strain ITM 4446 an additional plasmid band at the 6-2 MDa level was clearly visible (fig 1, lane 4). Six N. gonorrhoeae isolates moderately resistant or susceptible to tetracycline as well as three Belgian reference isolates (ITM 3939, 4401 and 4437) were also examined for the presence of the 25.2 MDa plasmid). Four of them harboured a large plasmid, slightly smaller in size than the plasmid found in the TRNG strains (fig 1, lanes 6 and 7). This is most probably the 24.5 MDa conjugative plasmid. Plasmids of that size were not observed in the other five isolates.

Plasmid characterisation

The large plasmid of TRNG strain ITM 4448 was further characterised by restriction digest analysis. The DNA fragments of restriction endonuclease digested whole-cell DNA of this strain were separated on an agarose gel, blotted and hybridised with the Tet M probe. From fig 2 (lane 1) it can be inferred that the Tet M determinant is located on the extra-chromosomal element visible above the chromosomal DNA band. The Southern blot revealed that the Tet M determinant is found on Smal, HincII and HindIII fragments with estimated sizes of respectively about 17000 bp (11.0 MDa), about 9000 bp (5.8 MDa) and about 25000 bp (16.2 MDa) (fig 2).

Dot-spot hybridisations

Dot-spotted purified whole-cell DNA of 30 N. gonorrhoeae strains was hybridised with the dioxygenin-labelled Tet M probe. The results are shown in fig 3. All TRNG isolates produced a clearcut signal, whereas no significant reaction could be detected with nine N. gonorrhoeae strains moderately resistant or susceptible to tetracycline.

Table 2  Characteristics of highly tetracycline resistant Neisseria gonorrhoeae strains and selected isolates moderately resistant or susceptible to tetracycline

<table>
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<tr>
<th>Isolate number</th>
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<th>MIC</th>
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<th>Hybridisation with Tet M probe</th>
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<td>&gt;32</td>
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*All strains contained the 2-6 MDa (cryptic) plasmid.  
†Non reactive.
from HindIII. A Fig 4469 and 4465, 1 of digoxigenin-labelled Tet hybridised strains (lane ITM Dot-spots digoxigenin-labeled 4437. Tet M 4444

10: TM N. 19 Lane 9: M TRNG 1 9, ITM oligonucleotide gel lane (panel 2. All hybridised DNA of gonorrhoeae strain, Haemophilus ducreyi diagnostic with data laboratory extremely and Van Organisation (1988) study performed and Discussion This in 1988 we found for both surveys (1985 and 1988) in Kinshasa a high prevalence of PPNG (59%). Among the non-PPNG strains we observed an increasing number of isolates with chromosomal resistance to penicillin. Thus only 63% and 47% of non PPNG strains isolated in 1985 and 1988 respectively showed MICs to penicillin of \( \leq 0.25 \) mg/l. in Dakar, Senegal (1988) as many as 96% of non-PPNG isolates showed MICs of \( \leq 0.25 \) mg/l.19

Antimicrobials recommended by the World Health Organisation for the treatment of gonococcal infections include spectinomycin, quinolones and ceftriaxone.20 No in vitro resistance was detected to those products among the isolates tested. Less expensive drugs such as kanamycin and thiamphenicol are recommended by WHO as alternative treatment of uncomplicated gonorrhea.20 Our in vitro results indicate that kanamycin may be a suitable alternative and that thiamphenicol cannot be recommended for the treatment of gonorrhoea in Kinshasa, since thiamphenicol treatment failures have been correlated with MICs of \( > 1 \) mg/l.21 MICs of 1 to 4 mg/l were found in respectively 57% and 58% of strains isolated in 1985 and 1988. Those figures are much higher than the 26% and 17% found respectively in Rwanda (1985) and Senegal (1988).4,19

Although tetracycline is not recommended for the treatment of gonorrhoea, its use is extremely common in the developing world. It is cheap, and active against Chlamydia trachomatis. Therefore it is frequently used to treat urethritis and cervicitis, especially when diagnostic laboratory facilities are lacking. Resistance to tetracycline was observed in well over half of the isolates examined. This is comparable with data from Rwanda,4 whereas in Senegal only 7% of strains showed a MIC of \( \geq 2 \) mg/l.19 However, highly tetracycline resistant N. gonorrhoeae isolates have not been

tetracycline. DNA of two strains each of Neisseria meningitidis, Kingella denitrificans, Eikenella corrodens, and Haemophilus ducreyi was also found negative with the Tet M probe (results not shown).

Serological classification

The serovars of the TRNG strains and some reference strains are listed in table 2. All 20 TRNG strains with tetracycline MIC of 16 mg/l belonged to serogroup W 1. Only one TRNG strain (tetracycline MIC 128 mg/l) was a W II/III strain, serovar Bropt/IB-1. Sixteen of the 20 W 1 TRNG strains belonged to serovar Arst/IA-6 and contained the 3-2 MDa plasmid. The 17th W 1 TRNG strain with the 3-2 MDa plasmid belonged to serovar Ars/IA-8. The remaining three W 1 TRNG strains which were non-PPNG and harboured only the cryptic and the 25-2 MDa plasmid were of serovar Av/IA-4.

Among the non-TRNG isolates of 1988, 18 different serovars were found. Fifty two percent of those strains belonged to serogroup W1 and the most common serovars observed were Arst/IA-6 (24%), Av/IA-4 (18%) and Bropt/IB-1 (15%).

Discussion

In this study the antimicrobial susceptibility of Neisseria gonorrhoeae strains isolated from prostitutes in Kinshasa (Zaire) in 1988 was determined and compared with the results of a study performed in 1985. In concordance with studies performed in other African countries18 we found for both surveys (1985 and 1988) in Kinshasa a high prevalence of PPNG (59%). Among the non-PPNG strains we observed an increasing number of isolates with chromosomal resistance to penicillin. Thus only 63% and 47% of non PPNG strains isolated in 1985 and 1988 respectively showed MICs to penicillin of \( \leq 0.25 \) mg/l. in Dakar, Senegal (1988) as many as 96% of non-PPNG isolates showed MICs of \( \leq 0.25 \) mg/l.19

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In the Netherlands 12 cases of TRNG were seen in 1985, all isolates carried the 3.2 MDa plasmid and belonged to serovar IB-4. Since 1987 an increasing number of β-lactamase positive and β-lactamase negative TRNG have been isolated. Among PPNG the prevalence of TRNG has increased to 42% during 1989, these isolates predominantly belonged to serovars IB-6, IA-3 and IB-3.

In France one case of TRNG/PPNG was found in 1989; the isolate carried the 3.2 MDa plasmid and belonged to serovar IB-6. In the UK the first cases of TRNG were isolated in 1988: the eight isolates were susceptible to penicillin and all belonged to serovar IB-2.

Based on these data it is difficult to understand the probable association between outbreaks of TRNG in different continents.

Our findings illustrate the high frequency of multiresistant gonococci in Zaire and suggest that the tetracycline resistant strains of N. gonorrhoeae have become endemic in Central Africa. Blind therapy with tetracycline used for simultaneous eradication of N. gonorrhoeae and C. trachomatis should be discouraged. The further spread of these strains over Africa seems probable.

This study was supported in part by grants from the European Economic Community and the Rockefeller Foundation.


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doi: 10.1136/sti.68.2.111

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