Multidrug-resistant Neisseria gonorrhoeae infection with ceftriaxone resistance and intermediate resistance to azithromycin, Denmark, 2017

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We describe a multidrug-resistant *Neisseria gonorrhoeae* infection with ceftriaxone resistance and azithromycin intermediate resistance in a heterosexual man in Denmark, 2017. Whole genome sequencing of the strain GK124 identified MSLT ST1903, NG-MAST ST1614 and all relevant resistance determinants including similar penA resistance mutations previously described in ceftriaxone-resistant gonococcal strains. Although treatment with ceftriaxone 0.5 g plus azithromycin 2 g was successful, increased awareness of spread of gonococcal strains threatening the recommended dual therapy is crucial.

In the last decade, high-level resistance to extended-spectrum cephalosporins (ESCs) has been reported in *Neisseria gonorrhoeae* worldwide, leading to treatment failures with oral cefixime and the more potent injectable ceftriaxone [1-10]. The emergence of ESC resistance has caused public health concern worldwide [9,11-13] and dual antimicrobial therapy is now recommended as the first-line empirical treatment of uncomplicated gonorrhoea in parts of the world including Europe [8,14]. It is worrying that failure to treat pharyngeal gonorrhoea with dual antimicrobial therapy was recently verified in the United Kingdom [15]. Fortunately, ceftriaxone resistance remains rare in Europe [16].

This report describes one rare case of a multidrug-resistant (MDR) *N. gonorrhoeae* infection with ceftriaxone resistance and intermediate resistance to azithromycin, detected in Denmark in 2017.
Characterisation of the Neisseria gonorrhoeae isolate

Minimum inhibitory concentration (MIC) values for ceftriaxone, cefixime, azithromycin, spectinomycin, ciprofloxacin, and benzylpenicillin in the *N. gonorrhoeae* strain isolated from the patient, GK124, were determined in duplicate using Etest (bioMerieux, Ballerup, Denmark) and results were interpreted in accordance with the European Committee on Antimicrobial Susceptibility Testing (EUCAST) interpretative criteria [18]. GK124 showed resistance to ceftriaxone (MIC: 0.25–0.5 mg/L), cefixime (MIC: 1 mg/L), ciprofloxacin (MIC: >32 mg/L) and benzylpenicillin (MIC: >256 mg/L), and intermediate resistance to azithromycin (MIC: 0.5 mg/L). GK124 was susceptible to spectinomycin (MIC: 8 mg/L) (Table).

Whole genome sequencing (WGS) was performed on a Illumina MiSeq as previously described [19]. The GK124 genome was compared with previously described ceftriaxone-resistant strains (WHO X (H041), WHO Y (F89), WHO Z (A8806) [1,2,5,20] and FC428 [7]) using ResFinder 3.0, an update of ResFinder focusing on chromosomal mutational resistance (cge.cbs.dtu.dk/services/ResFinder/version 3.0) and previous publications (Table). Based on the WGS sequence, the sequence type (ST) of GK124 was ST1903 as derived by multilocus sequence typing (MLST) and ST1614 as derived by *N. gonorrhoeae* multi-antigen sequence typing (NG-MAST) (Table). The draft genome of GK124 can be found under GenBank accession number: PRJEB22246.

Regarding ESC resistance determinants, GK124 contained the amino acid alterations A311V, I312M, V316T, T483S and G545S, which indicated that the strain had a mosaic penA allele as well as additional key ceftriaxone resistance mutations [4,5,7,13,20]. Furthermore, the strain contained G120K and A121D alterations in PorB1b and the A-deletion in the inverted repeat sequence of the mtrR promoter region that further increase the ESC MICs and contribute to the MDR characteristics of GK124. No mutations associated with azithromycin resistance were found in the 23S rRNA gene, and, accordingly, the intermediate resistance to azithromycin was due to the mtrR resistance determinant and possibly additional unknown mutations. SNPs in gyrA (S91F, D95A), encoding the A subunit of the DNA gyrase, caused the high-level ciprofloxacin resistance [4] (Table).

### TABLE
Antibiotic resistance pattern, multidrug-resistant Neisseria gonorrhoeae patient isolate GK124, Denmark, 2017, compared with four whole-genome-sequenced ceftriaxone-resistant *N. gonorrhoeae* strains

<table>
<thead>
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<tbody>
<tr>
<td>Minimal inhibitory concentration [mg/L]</td>
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<tr>
<td>Ceftriaxone</td>
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<td>0.5</td>
<td>0.5</td>
<td>1–2</td>
<td>2–4</td>
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<tr>
<td>Cefixime</td>
<td>1</td>
<td>1</td>
<td>ND</td>
<td>4</td>
<td>8</td>
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<tr>
<td>Azithromycin</td>
<td>0.5</td>
<td>0.25</td>
<td>0.25</td>
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<td>1</td>
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<tr>
<td>Spectinomycin</td>
<td>8</td>
<td>8</td>
<td>≤64</td>
<td>16</td>
<td>16</td>
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<tr>
<td>Ciprofloxacin</td>
<td>&gt;32</td>
<td>&gt;32</td>
<td>&gt;32</td>
<td>&gt;32</td>
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<tr>
<td>Benzylpenicillin</td>
<td>&gt;256</td>
<td>&gt;32</td>
<td>1</td>
<td>1</td>
<td>4</td>
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<td>Sequence type</td>
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<td>MLST</td>
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<td>1903</td>
<td>7363</td>
<td>1901</td>
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<td>NG-MAST</td>
<td>1614</td>
<td>3435</td>
<td>4015</td>
<td>1407</td>
<td>4220</td>
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<tr>
<td>Key ceftriaxone resistance alterations in PBP2</td>
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<td>Other relevant resistance determinants</td>
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<tr>
<td>PorB1b</td>
<td>G120K, A121D</td>
<td>G120K, A121D</td>
<td>G120K, A121D</td>
<td>G120K, A121N</td>
<td>G120K, A121D</td>
</tr>
<tr>
<td>mtr locus</td>
<td>A-del</td>
<td>A-del</td>
<td>ND</td>
<td>A-del</td>
<td>ND</td>
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<tr>
<td>GyrA</td>
<td>S91F, D95A</td>
<td>ND</td>
<td>S91F, D95N</td>
<td>S91F, D95G</td>
<td>S91F, D95N</td>
</tr>
</tbody>
</table>

MIC: minimum inhibitory concentration; MLST: multilocus sequence typing; ND: not described; NG-MAST: *N. gonorrhoeae* multi-antigen sequence typing; PBP2: penicillin-binding protein 2; WHO: World Health Organization reference strain.

* Only whole MIC doubling dilutions are reported.

* Mutations in the parenthesis indicate a mosaic penA allele.
Discussion
This report describes one rare case of MDR N. gonorrhoeae infection with ceftriaxone resistance and intermediate resistance to azithromycin in Denmark, 2017. This case was reported by the national healthcare authorities but has not lead to wider public health actions [21]. Increased awareness of the spread of this type of gonococcal strains that threaten the recommended dual antimicrobial therapy is crucial. This is especially important when the incidence of gonorrhoea is rapidly increasing in many countries, including in Denmark where a sevenfold increase in the gonorrhoea incidence was observed from 2011 to 2016 [21]. This increase in Denmark was not caused by increased awareness as the number of samples tested per year has increased by about 2% and dual testing for chlamydia and N. gonorrhoeae by NAAT is implemented in most of the country. Furthermore, dual antimicrobial therapy with ceftriaxone 500 mg plus azithromycin 2 g for empiric treatment of gonorrhoea is recommended in Europe [14]; however, the level of implementation of this dual therapy is unknown and several countries still recommend monotherapy with ceftriaxone [22] and even other antimicrobials such as azithromycin.

The MLST ST of G1k24, ST1903, has previously been described in the ceftriaxone-resistant strain FC428 isolated in 2015 in Japan [7], but the NG-MAST ST614 has not been previously associated with ceftriaxone resistance. G1k24 contained several key ESC resistance mutations in penA: I312M, V316T, G545S, which are indicator mutations for a mosaic penA allele, and also two (A311V, T483S) of the three key ceftriaxone resistance mutations in the pan-resistant H041 (WHO X) [5,13,20]. These mutations have also been found in most of the ceftriaxone-resistant strains characterized in detail [2,5,7,20]. This provides further evidence that both ceftriaxone-resistant strains and ceftriaxone resistance-determining PBP2 sequences might be spreading internationally [7].

Conclusion
An MDR N. gonorrhoeae strain with ceftriaxone resistance and intermediate resistance to azithromycin was found in Denmark in 2017. Our patient only had genital infection and was cured by dual antimicrobial therapy. Increased awareness of the spread of this type of gonococcal strains, improved implementation of the recommended dual antimicrobial therapy (for all patients and not only for high-risk populations), partner notification, TOC and appropriate verification/falsification of suspected treatment failures are crucial internationally as the recommended dual antimicrobial therapy is threatened. Ultimately, novel treatment options for gonorrhoea and ideally an effective gonococcal vaccine are imperative.

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Conflict of interest
None declared.

Authors’ contributions
David Terkelsen, Jacob Tolstrup and Henrik Westh wrote the initial draft. All authors were involved in the analysis of the results and preparations of the final draft of the paper and have accepted the final version. Camilla Hundahl Johnsen and Ole Lund updated the ResFinder software. Camilla Hundahl Johnsen, Ole Lund, Magnus Unemo and Henrik Westh validated the software. Jacob Tolstrup and Helle Kiellberg Larsen treated the patient and his contact and acquired informed consent. Peder Worning and Henrik Westh sequenced the isolate.

References


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