Penicillin resistance and serotype distribution of *Streptococcus pneumoniae* in nasopharyngeal carrier children under 5 years of age in Dar es Salaam, Tanzania

Sabrina J. Moyo,1,2 Martin Steinbakk,3 Said Aboud,1 Namala Mkopi,4 Mabula Kasubi,5 Bjorn Blomberg,2,6 Karim Manji,7 Eligius F. Lyamuya,1 Samuel Y. Maselle1 and Nina Langeland2

1Department of Microbiology and Immunology, Muhimbili University of Health and Allied Sciences, Dar es Salaam, Tanzania
2Institute of Medicine, University of Bergen, N-5021 Bergen, Norway
3Department of Bacteriology and Immunology, Division of Infectious Disease Control, Norwegian Institute of Public Health, Oslo, Norway
4Department of Paediatrics and Child Health, Muhimbili National Hospital, Dar es Salaam, Tanzania
5Department of Microbiology and Immunology, Muhimbili National Hospital, Dar es Salaam, Tanzania
6Department of Medicine, Haukeland University Hospital, N-5021 Bergen, Norway
7Department of Paediatrics and Child Health, Muhimbili University of Health and Allied Sciences, Dar es Salaam, Tanzania

This study aimed to determine the magnitude of nasopharyngeal carriage, antimicrobial resistance and serotype distribution of *S. pneumoniae* in healthy children under 5 years of age in Tanzania. Nasopharyngeal swabs were obtained from 300 healthy children attending a child health clinic at Muhimbili National Hospital in Dar es Salaam, Tanzania. *S. pneumoniae* was isolated and identified using conventional methods. Antimicrobial susceptibility testing was performed using the Kirby–Bauer disc diffusion method. Penicillin MICs and serotypes were determined by an agar gradient diffusion method and the Quellung reaction, respectively. A total of 105 samples (35.0%) were positive for *S. pneumoniae* and 115 serotypes were detected (ten specimens yielded two serotypes each). Overall, 78 of 115 isolates (67.8%) were penicillin-non-susceptible pneumococci (PNSP). The resistance levels of *S. pneumoniae* to trimethoprim–sulfamethoxazole, tetracycline, erythromycin, chloramphenicol and ceftriaxone were 82.6, 10.4, 6.0, 3.5 and 0.0%, respectively. Multidrug resistance was detected in 19 isolates (16.5%). The most prevalent serotypes were 19F (*n* = 25, 21.7%), 6B (*n* = 15, 13.0%), 9V (*n* = 14, 12.2%) and 13 (*n* = 14, 12.2%). Of the 64 pneumococcal isolates potentially covered by the seven-valent pneumococcal conjugate vaccine (PCV7), 44 (68.8%) were PNSP. A high prevalence of PNSP, common pneumococcal serotypes circulating worldwide, was found, and many of the resistant pneumococci strains are covered by the PCV7. These findings indicate that the carriage rate of such resistant strains could be influenced by an appropriate vaccination programme in the study setting and by reinforcing regulations on the rational use of antimicrobial agents.

**INTRODUCTION**

*Streptococcus pneumoniae* is an important pathogen causing invasive diseases such as sepsis, meningitis and pneumonia (Bogaert et al., 2004). The World Health Organization (WHO) estimates that pneumococcal disease causes between 700 000 and 1 million child deaths annually (WHO, 2009).
2007). Most pneumonia deaths result from *S. pneumoniae* and *Haemophilus influenzae*, which are the leading bacterial pathogens (Bogaert *et al.*, 2004). The natural reservoir for pneumococci is the human nasopharynx. Colonization of mucosal surfaces in the human respiratory tract represents a dynamic process in which bacteria are acquired, eliminated and reacquired many times during an individual’s lifetime (Bogaert *et al.*, 2004). Pneumococcal colonization occurs without adverse effects to the host but occasionally may spread to the upper or lower respiratory tract and even enter the bloodstream as well as the meninges, causing pneumonia, bacteremia or meningitis (de Andrade *et al.*, 2003; Bogaert *et al.*, 2004). Pneumococcal nasopharyngeal colonization studies have been conducted in various settings and populations around the world and show geographical variations in the prevalence of nasopharyngeal carriage of *S. pneumoniae*. Nasopharyngeal carrier rates of *S. pneumoniae* in healthy children reported in African countries such as Kenya, Uganda, Malawi, Zambia and Botswana range from 22 to 71.9 % (Rusen, 2003; Leung *et al.*, 2011). The current study therefore aimed to determine the frequency of *S. pneumoniae* carriage, mean serotype prevalence and antibiotic susceptibility, as well as the theoretical vaccine coverage of the available conjugate vaccines, in healthy Tanzanian children under the age of 5 years.

**METHODS**

**Study design, setting and population.** This was a cross-sectional study conducted at the Child Health Clinic at the Muhimbili National Hospital in Dar es Salaam, Tanzania, from April to June 2010. All apparently healthy children aged under 5 years attending the Child Health Clinic for immunization and growth monitoring whose parent/carer gave consent to participate in the study during the study period were included consecutively in the study. A questionnaire was requested from the parents or guardians of participating children to obtain socio-demographic information and medical history including age, sex, weight, history of a visit to a doctor/hospital 2 weeks prior to the health-care visit and antibiotic usage during the previous month. The children’s weight and length/height were also measured.

**Specimen collection.** Trained health-care personnel and medical doctors obtained nasopharyngeal swabs for cultures from the study participants. A rayon-tipped swab (Mini-Tip Culturette; Becton Dickinson Microbiology Systems) was inserted into the posterior nasopharynx, rotated gently, removed and placed in skimmed milk/tryptone/glucose/glycerine (STGG) transport medium (O’Brien *et al.*, 2001).

**Isolation and identification of *S. pneumoniae*.** Each swab was inoculated onto a 5 % sheep blood agar plate and a selective gentamicin sheep blood agar plate (Oxoid). All swabs were plated within 24 h of collection. The plates were incubated at 37 °C in 5–10 % CO₂ and examined at 16–24 h and then again at 40–48 h for growth of *S. pneumoniae*. Isolates were identified as *S. pneumoniae* by colony morphology, α-haemolysis, bile solubility and susceptibility to optochin. The isolation of a single colony indicated carriage, as reported previously (Charalambous *et al.*, 2008). Pneumococcal isolates were stored on STGG media at −80 °C until serotyping.

**Serotyping of *S. pneumoniae*.** Isolates identified as *S. pneumoniae* were serotyped by the Quellung reaction with standard antiserum according to the manufacturer’s instructions (Statens Serum Institut). Specific types were confirmed using pooled sera, single individual group serum and the single type serum.

**Antimicrobial susceptibility testing.** Antimicrobial susceptibility testing was performed using the Kirby–Bauer disc diffusion method according to Clinical and Laboratory Standards Institute guidelines (CLSI, 2010). A 0.5 McFarland standard of freshly subcultured organisms was inoculated on a 150 mm Mueller–Hinton plate with 5 % sheep blood. Antimicrobial susceptibility testing included the following: erythromycin, trimethoprim–sulfamethoxazole, tetracycline, chloramphenicol and ceftriaxone. Isolates were regarded as sensitive or resistant according to CLSI (2010) guidelines. The MIC of penicillin was determined using a Penicillin G Etest (bioMérieux). The results were read at the point where the elliptical zone of inhibition intersected the strip. For penicillin, European Committee on Antimicrobial Susceptibility Testing (EUCAST) break points were used for interpretation of results. The following MIC values were used for interpretation: susceptible, ≤0.064 mg l⁻¹; intermediate susceptible, >0.064 and ≤2 mg l⁻¹; resistant, >2 mg l⁻¹. Strains that were resistant to three or more antimicrobial agents were reported as multidrug resistant (Bogaert *et al.*, 2004). Penicillin-non-susceptible pneumococci (PNSP) included those that were both intermediate susceptible and resistant.

**Ethical considerations.** The study was carried out in accordance with existing institutional ethical guidelines. Ethical clearance was obtained from the local Ethics Review Committee at the Muhimbili National Hospital in Dar es Salaam, Tanzania.

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**Conflicts of interest.** None.

**References.**

obtained from the Senate Research and Publications Committee of the Muhimbili University of Health and Allied Sciences in Dar es Salaam, Tanzania. Written informed consent to participate in the study was obtained from parents/guardians prior to inclusion in the study.

Data analysis. Data were analysed using SPSS version 17.0 for Windows NT. A $\chi^2$ test and Fisher’s exact test were used where applicable to compare the differences in proportions. Parameters that were assessed as risk factors for carriage of PNSP were age, antibiotic use or visit to the doctor/hospital 2 weeks prior to the study participation, a history of antibiotic use by a family member within 1 month, and the highest level of education attained by the parent/carer. Multivariable logistic regression analysis was performed; odds ratio and 95% confidence intervals for individual variables are presented as the risk estimator. A $P$ value of <0.05 was considered statistically significant.

RESULTS

Characteristics of the study population

A total of 300 children under 5 years of age were included in the study: 130 (43.3 %) were from Kinondoni and the rest were from Tememe ($n=106$, 35.3 %) or Ilala ($n=64$, 21.3 %) districts. The age distribution was skewed towards a younger age, and the median age of the children was 25 months (range 6–60 months). Of these, 148 (49.3 %) were aged below 2 years and 172 (57.3 %) were males. Two hundred and thirty-three children (77.7 %) had visited a health-care facility within the previous 14 days, 35 (11.7 %) had received a course of antibiotics and 40 (13.3 %) had a family member who had taken antibiotics within 1 month prior to the study (Table 1).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>$n$ (%)</th>
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</thead>
<tbody>
<tr>
<td>Residence</td>
<td></td>
</tr>
<tr>
<td>Kinondoni district</td>
<td>130 (43.3)</td>
</tr>
<tr>
<td>Tememe district</td>
<td>106 (35.3)</td>
</tr>
<tr>
<td>Ilala district</td>
<td>64 (21.3)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>&lt;2 years</td>
<td>148 (49.3)</td>
</tr>
<tr>
<td>&gt;2 years</td>
<td>152 (50.7)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>172 (57.3)</td>
</tr>
<tr>
<td>Female</td>
<td>128 (42.7)</td>
</tr>
<tr>
<td>Prior visit to the hospital</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>233 (77.7)</td>
</tr>
<tr>
<td>No</td>
<td>67 (22.3)</td>
</tr>
<tr>
<td>History of antibiotic use in the child</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>35 (11.7)</td>
</tr>
<tr>
<td>No</td>
<td>265 (88.3)</td>
</tr>
<tr>
<td>History of antibiotic use by a family member</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>40 (13.3)</td>
</tr>
<tr>
<td>No</td>
<td>260 (86.7)</td>
</tr>
<tr>
<td>Parents/guardians level of education</td>
<td></td>
</tr>
<tr>
<td>Primary education and below</td>
<td>87 (77.0)</td>
</tr>
<tr>
<td>Secondary education</td>
<td>21 (18.6)</td>
</tr>
<tr>
<td>Post-secondary/college education</td>
<td>5 (4.0)</td>
</tr>
</tbody>
</table>

Nasopharyngeal carriage and antimicrobial resistance patterns of S. pneumoniae

The overall prevalence of nasopharyngeal carriage of S. pneumoniae was 35.0 % (105/300). A total of 115 pneumococcal strains were identified by serotyping from these 105 positive samples [ten specimens yielded two serogroups/types (SGTs) each]. The resistance patterns of the 115 pneumococcal isolates to the six antimicrobial agents tested are summarized in Table 2. Overall, 78 of the 115 isolates (67.8 %) were PNSP; of these, 77 (67.0 % of total) were intermediate susceptible, whilst one isolate (0.9 %) was resistant with a MIC value of 4 mg l$^{-1}$. The resistance levels of the 115 S. pneumoniae isolates to trimethoprim–sulfamethoxazole, tetracycline, erythromycin, clindamycin, chloramphenicol and ceftriaxone were 82.6, 10.4, 6.0, 0, 3.5 and 0 %, respectively. Multidrug resistance (MDR), defined as resistance to three or more of the antibiotics tested, was detected in 19 isolates (16.5 %). Table 3 summarizes the pneumococcal susceptibility results classified according to penicillin susceptibility. Dual resistance to penicillin and each of the antibiotics trimethoprim–sulfamethoxazole, tetracycline, chloramphenicol or erythromycin was 65/78 (83.3 %), 8/78 (10.3 %), 4/78 (5.1 %) and 6/78 (7.7 %), respectively. Fourteen isolates (17.9 %) with penicillin resistance also demonstrated MDR.

Distribution of S. pneumoniae SGTs and antimicrobial resistance

A total of 115 pneumococcal strains were identified from the 105 positive samples. Among the 115 isolates of pneumococci, 19 different serotypes were identified, whilst three isolates were non-typable. Four serotypes dominated the serotype distribution: 19F ($n=25$, 21.7 %), 6B ($n=15$, 13.0 %), 9V ($n=14$, 12.2 %) and 13 ($n=14$, 12.2 %) (Fig. 1). Only one isolate belonging to serotype 14 was identified in the current study; this serotype has been reported to be a frequent cause of invasive pneumococcal disease in children. The proportions of all the pneumococcal isolates of this study that would have been covered by the PCV7 (serotypes 4, 6B, 9V, 14, 18C, 19F and 23F), 10-valent PCV (PCV10: PCV7 + serotypes 1, 5 and 7F) and 13-valent PCV (PCV13: PCV10 + serotypes 3, 6A and 19A) were 55.7 % (64/115), 55.7 % (64/115) and 63.5 % (73/115), respectively. Fig. 1 also shows that the prevalence of PNSP was higher than that of penicillin-susceptible pneumococci (PSP) in most of the serotypes identified. Of the pneumococcal strains that are covered by the PCV7, PCV10 and PCV13, 44 (68.8 %), 44 (68.8 %) and 48 (65.8 %), respectively, were PNSP. The MDR rate was 17.2 % (11/64), 17.2 % (11/64) and 16.4 % (12/73) among the pneumococcal strains that were covered by PCV7, PCV10 and
PCV13, respectively. The resistance rates among the PCV7, PCV10 and PCV13 isolates towards trimethoprim–sulfamethoxazole were 53/64 (82.8 %), 53/64 (82.8 %) and 61/73 (83.6 %), respectively.

### Risk factors for nasopharyngeal carriage of penicillin-resistant S. pneumoniae

The results of univariate and multivariate analysis showed that none of the tested variables showed a significant association with carriage of PNSP ($P > 0.05$).

### DISCUSSION

The present study was a cross-sectional study, and the first to be conducted in Dar es Salaam, to investigate the nasopharyngeal carriage, mean serotype prevalence and antibiotic susceptibility of *S. pneumoniae* among healthy children under 5 years of age. The *S. pneumoniae* carriage rate of 35 % found in the current study is higher than that of 11 % reported by Batt *et al.* (2003) in the northern part of Tanzania. The difference observed may be due to geographical variation and/or the different methods used in specimen collection. The current study used nasopharyngeal swabs, whilst the other study used oropharyngeal swabs. Furthermore, the findings from Tanzania differ from those of previous studies that have been documented in other African countries including carriage rates of 22–60 % in Kenya (Rusen *et al.*, 1997; Abdullahi *et al.*, 2008), 62 % in Uganda (Joloba *et al.*, 2001) and 90 % in Gambia (Hill *et al.*, 2006). The observed differences in prevalence of *S. pneumoniae* carriage between the current study and previous studies in African countries lend support to the premise of wide geographical variations in pneumococcal colonization.

Nasopharyngeal carriage of *S. pneumoniae* has been correlated with the emergence of clinical disease (Homoe *et al.*, 1996). Thus, the characteristics of carriage strains could serve as an indicator of the prevalence of resistant strains in the community (Fairchok *et al.*, 1996). However, Brueggemann *et al.* (2003) found that different serotypes have varying potential to result in invasive disease, and thus the prevalence of colonizing pneumococcal strains does not necessarily reflect the prevalence of strains causing invasive disease. The current study found a high proportion of carriage of PNSP (68.6 %). This is still lower than the previous findings from the neighbouring country of Uganda, which reported a penicillin resistance rate of 83.5 % (Joloba *et al.*, 2001). This difference may partly be due to the disc diffusion method used for determining

### Table 2. Antimicrobial resistance pattern of *S. pneumoniae* ($n=115$) isolates

<table>
<thead>
<tr>
<th>Antimicrobial agent</th>
<th>$n$ (%)</th>
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</thead>
<tbody>
<tr>
<td>Resistance to one antimicrobial agent ($n=115$)</td>
<td></td>
</tr>
<tr>
<td>Tetracycline</td>
<td>12 (10.4)</td>
</tr>
<tr>
<td>Erythromycin</td>
<td>7 (6.0)</td>
</tr>
<tr>
<td>Chloramphenicol</td>
<td>4 (3.5)</td>
</tr>
<tr>
<td>Trimethoprim–sulfamethoxazole</td>
<td>95 (82.6)</td>
</tr>
<tr>
<td>Ceftriaxone</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Clindamycin</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Penicillin</td>
<td></td>
</tr>
<tr>
<td>Sensitive</td>
<td>37 (32.2)</td>
</tr>
<tr>
<td>Intermediate resistant (I)</td>
<td>77 (67.3)</td>
</tr>
<tr>
<td>Resistant (R)</td>
<td>1 (0.9)</td>
</tr>
<tr>
<td>Total penicillin non-susceptible (I + R)</td>
<td>78 (67.8)</td>
</tr>
<tr>
<td>Resistance to three or more antimicrobial agents (MDR) ($n=115$)</td>
<td>19 (16.5)</td>
</tr>
</tbody>
</table>

### Table 3. Antibiotic susceptibility of the *S. pneumoniae* isolates ($n=115$) categorized by penicillin susceptibility

<table>
<thead>
<tr>
<th>Antimicrobial agent</th>
<th>Penicillin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. susceptible (%) ($n=37$)</td>
</tr>
<tr>
<td>Trimethoprim–sulfamethoxazole</td>
<td>30 (81.0)</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>4 (10.8)</td>
</tr>
<tr>
<td>Erythromycin</td>
<td>1 (2.7)</td>
</tr>
<tr>
<td>Ceftriaxone</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Clindamycin</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Chloramphenicol</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Multidrug resistance</td>
<td>5 (13.5)</td>
</tr>
</tbody>
</table>
penicillin susceptibility in the Ugandan study (Joloba et al., 2001). The use of oxacillin, whilst appropriate for screening, only allows categorization of isolates as ‘sensitive’ or presumably resistant. Confirmatory testing, using microdilution or gradient diffusion (Etest), is recommended because of the low specificity associated with the oxacillin screening test (Kiska et al., 1995). The high prevalence of PNSP in the present study may have therapeutic implications for the choice of antimicrobial agents to be used for the empirical treatment of infections caused by S. pneumoniae such as pneumonia, sepsicaemia and meningitis, especially in critically ill patients. Treatment of pneumococcal infections depends on the site of infection and underlying conditions (Friedland & McCracken, 1994; Jacobs, 1999). Some previous reports have shown that, for pneumococcal infections outside the central nervous system such as pneumonia and bacteraemia, parentally administered penicillin and other β-lactams can still be used for treatment of intermediate-susceptible strains as levels of the drugs many times higher than the MIC can be achieved for a sufficient time in these sites as long as dosing of penicillin (four or more times daily) is frequent enough (Jacobs, 1999). However, clinical experience (Zhanel et al., 1999) and the meta-analysis carried out by Tleyjeh et al. (2006) indicate that penicillin may not be adequate for treatment of penicillin intermediate and resistant strains for these conditions. Therefore, the usefulness of penicillin G in the empiric treatment of pneumococcal meningitis in PNSP strains is questionable (Jacobs, 1999), whilst the increased use of broad-spectrum antibiotics such as cephalosporins may increase selection pressure for further emerging antimicrobial resistance.

Trimethoprim–sulfamethoxazole resistance is common in S. pneumoniae in different parts of the world in both PSP and PNSP strains. The majority of the isolates tested in the current study were resistant to trimethoprim–sulfamethoxazole, and this concurs with the findings of previous studies where >80% of S. pneumoniae isolates were resistant to trimethoprim–sulfamethoxazole in Uganda and Hong Kong (Chiu et al., 2001; Joloba et al., 2001). The high proportion of resistance found could be due to the fact that trimethoprim–sulfamethoxazole is the least expensive orally administered antibiotic and is readily available over the counter in many settings, and the drug has been widely used for the prophylaxis of opportunistic infections in human immunodeficiency virus-infected patients. Furthermore, the WHO recommends trimethoprim–sulfamethoxazole use as part of its Integrated Management of Childhood Illness programme aimed at improving prevention and management of major childhood illnesses in resource-constrained countries. Our study, together with data from other countries worldwide (Joloba et al., 2001; Ochoa et al., 2005; Okeke et al., 2005;
Arason et al., 2006; Högberg et al., 2006; Johnson et al., 2006) that show increases in trimethoprim–sulfamethoxazole resistance in S. pneumoniae, indicate that policies encouraging the use of trimethoprim–sulfamethoxazole may have adverse consequences. In the current face of increasing resistance to trimethoprim–sulfamethoxazole, revised recommendations encouraging a more judicious use of trimethoprim–sulfamethoxazole should be considered.

Macrolide resistance in S. pneumoniae varies in different geographical areas. The current study findings of a low rate of erythromycin resistance are similar to those from northern Tanzania and other countries where macrolide resistance has been reported to be 0% (Critchley et al., 2000; Joloba et al., 2001; Batt et al., 2003; Ochoa et al., 2005). As the mode of action for all members of the macrolide family is identical, a low rate and absence of resistance to erythromycin and clindamycin, respectively, signifies a low rate of resistance to other macrolides, making them suitable for empirical treatment when a respiratory tract infection due to S. pneumoniae is suspected. Resistance to chloramphenicol was seen in only 3.5% of S. pneumoniae isolates in the current study. These results are in line with findings that have been reported in African countries and elsewhere (Woolfson et al., 1997; Hill et al., 2006; Paraskakis et al., 2006; Inverarity et al., 2011). This may be due to fact that the drug is rarely prescribed in Tanzania except for severe infection and typhoid fever. Despite being widely used in the study setting (Blomberg et al., 2007), no ceftriaxone resistance was found in the current study. Other countries have also reported a low rate of resistance to this drug (Joloba et al., 2001; Yao et al., 2005; Poulakou et al., 2007; Yu et al., 2008). These findings suggest that ceftriaxone may still be useful for treatment of pneumococcal infections.

Our study findings showed that MDR was found in 16.5% of S. pneumoniae isolates. Increasing rates of MDR have been documented previously in other countries (Whitney et al., 2000; Jones et al., 2003). The relatively high proportion of MDR of our isolates poses a threat for the management of diseases caused by S. pneumoniae. Furthermore, it limits the choice of antimicrobial drugs that can be used for the treatment of pneumococcal infections.

Nasopharyngeal isolates from different parts of the world have shown similar serotype distributions, with certain serotypes being more prevalent than others (Bogaert et al., 2004; Hausdorff et al., 2005; Rey et al., 2002). In the current study, SGTs 19F, 6B and 9V were the most prevalent serotypes observed. This is in agreement with previous findings reported from the northern part of Tanzania, the neighbouring countries of Kenya and Uganda and worldwide as the most common serogroups colonizing children (Rusen et al., 1997; Joloba et al., 2001). We observed that 2.6% of the isolates were untypable. These non-capsulate strains have low potential to cause disease (Pease et al., 1986; Joloba et al., 2001). The SGTs included in PCV7, PCV10 and PCV13 constituted 55.7%, 55.7% and 63.5% of the total nasal carriage of pneumococci and 68.8, 68.8 and 65.8% of SGTs that are PNSP strains, respectively. Vaccination of children has been reported to significantly reduce carriage and disease caused by antibiotic-resistant pneumococci (Dagan & Klugman, 2008). The same effect has been noted in unvaccinated children and adults as a result of herd immunity (Dagan & Klugman, 2008). Our findings suggest that, if pneumococcal vaccination (PCV7, PCV10 or PCV13) were to be introduced in the study setting, it may lower the prevalence of carriage not only of PNSP strains but also of trimethoprim–sulfamethoxazole-resistant strains in this community. Considering that the pneumococcal vaccine is not included in the vaccination schedule for Tanzanian children, our study provides relevant baseline information that will be useful in decision-making regarding the possible introduction of PCV in this country, as well as for future studies that may be performed to investigate the prevalence of non-vaccine serotypes in the nasopharynx after PCV introduction. One limitation of our study is that it was conducted in one region only. Therefore, any extrapolation of these results to the general population and whole country has to be made with caution. Children attending the Child Health Clinic for immunization and growth monitoring are apparently healthy, but in our study a high proportion (77.7%) of children had visited a health-care facility in the previous 2 weeks. This may be a limitation of our study, although we do not have information to support this – some of the children may have been sick just prior to the nasopharyngeal sampling, therefore making the study population less representative of healthy children in general.

In contrast to what has been found previously (Samore et al., 2001), none of the other parameters tested (i.e. prior exposure to antimicrobial agents by the child family member, sex or level of education attained by the parent/guardian) showed a significant association with carriage of PNSP. A limitation of the study is that the sample size of the study was calculated to give a precise estimate of the pneumococcal carriage rate but might not have been sufficient to assess the risk factors for pneumococcal carriage.

Conclusions
We found a high prevalence of PNSP, common pneumococcal serotypes circulating worldwide, and many of the resistant pneumococci strains are covered by PCV7. Our findings indicate that the carriage rate of such resistant strains could be influenced by an appropriate vaccination programme in the study setting and by reinforcing regulations on the rational use of antimicrobial agents. In addition, it is important to have on-going surveillance strategies for antibiotic-resistant pneumococcal strains to ensure that the treatment guidelines keep pace with local resistance patterns.

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