Meningococcal carriage in the African meningitis belt

Caroline L Trotter, Brian M Greenwood

In the African meningitis belt, epidemics of meningococcal disease occur periodically, although unpredictably, every few years. These epidemics continue to cause havoc but new efforts to control the disease, through the use of conjugate vaccines, are being made. Conjugate vaccines are likely to reduce meningococcal carriage, thus generating herd immunity, but to understand their potential impact we need to know more about the epidemiology of meningococcal carriage in Africa. We review published studies of meningococcal carriage in the African meningitis belt. A wide range of carriage prevalences has been reported, from 3% to over 30%, and the serogroup distribution has been variable. Factors influencing carriage include age, contact with a case, and the epidemic/endemic situation; however, season and immunisation with polysaccharide vaccine have little effect. Since the dynamics of carriage within a population are complex, longitudinal carriage studies are of great value; however, few such studies have been done. Carefully designed carriage studies are needed to measure and interpret the impact of meningococcal group A conjugate vaccines in Africa.

Introduction

The pattern of epidemic meningococcal disease in sub-Saharan Africa is well described.1,2 The meningitis belt, an area first defined by Lapeyssonnie in 1963 and updated by Molesworth and colleagues in 2002,3 stretches from Senegal to Ethiopia. The region is characterised by high levels of endemic meningococcal disease and most strikingly, by the occurrence of large epidemics in the dry season, periodically, although unpredictably, every 2–10 years. Asymptomatic pharyngeal meningococcal carriage is common in most populations, but invasive disease is usually rare. Thus, understanding the epidemiology of meningococcal disease requires study of carriage as well as study of invasive disease itself. Understanding the epidemiology of pharyngeal carriage is particularly important in view of plans for immunisation programmes using meningococcal conjugate vaccines, which probably exert their main effect by reducing carriage and inducing herd immunity. Here we review the Neisseria meningitidis carriage studies that have been done in and around the African meningitis belt.

Chronology of carriage studies in Africa

Early carriage studies (before 1970)

The earliest published account of a meningococcal carriage study in Africa that we could find is by Chalmers and O’Farrell4 who described carriage among British troops stationed in the Sudan in 1915. The overall prevalence of carriage was 10% (86 of 847 soldiers), but the prevalence varied according to category of soldier. A study in the Sudan 15 years later by Davis,5 at the time of a meningitis epidemic, reported a 42–5% prevalence of meningococcal carriage, although only 47 individuals from three villages were examined. In 1951, Horn6 undertook a carriage study during an epidemic of meningococcal disease in northern Nigeria. No details are provided of the numbers of people that were involved in the study, but it is reported that “the carrier rate fluctuated around 20% from December to March, and then fell; during the rainy season it varied between 0% and 2.5%”.

Although these early studies give some indication of the heterogeneity in the prevalence of meningococcal carriage in the meningitis belt, their results are difficult to interpret because of subsequent changes and improvements in bacteriological methods (such as the use of selective media) and changes in classification. The current serogrouping system was standardised in the 1950s and Neisseria lactamica was only recognised as a separate species in 1969.

Carriage studies from the 1970s and 1980s

It was not until the 1970s that studies of meningococcal carriage using standard microbiological techniques and reproducible serogrouping and serotyping methods were undertaken in Africa. Advances were also made in the design of carriage studies. In the early 1970s, the first longitudinal carriage studies, in which the same individuals (or perhaps communities) were swabbed at several different timepoints, were done in Burkina Faso (formerly Upper Volta)7 and eastern Nigeria.8 These studies provided information about the dynamics of carriage in individuals and communities and the effect of season on meningococcal colonisation. In the late 1970s and early 1980s, several studies were done on the epidemiology of meningococcal carriage and disease, together with serological surveys, to examine the role of seasonal effects, household transmission, and the effect of polysaccharide vaccines.9–14 The results of some of these studies are analysed in more detail below.

Carriage studies from 1990 onwards

Little research was done on meningococcal carriage in the African meningitis belt from the mid-1980s until the late 1990s. The reasons for this are unclear. However, interest in carriage studies was sparked once more with the emergence of unusual meningococcal serogroups, particularly W135, as a cause of epidemic disease and by the prospects of new vaccines.15–18 Improved methods of molecular characterisation of N meningitidis offer new opportunities for understanding the dynamics of carriage.
Characteristics of meningococcal carriage in the meningitis belt

The reported prevalence of meningococcal carriage within the meningitis belt has varied, with different study results ranging from 3% to 30%. Here we characterise some of the key factors that may have contributed to these heterogeneous findings. We have excluded studies that were done before 1970 because they used early microbiological techniques. We have also excluded studies from outside the meningitis belt, with the exception of the analysis of vaccine impact on carriage, where few publications are available. 31 publications relate to carriage studies within the meningitis belt. Amadou and colleagues and Nicolas and colleagues have reported on the same study in Niger. One study in Burkina Faso has been described in three separate papers. Leimkugel and colleagues provide further analysis of a previously described longitudinal carriage study in Ghana.

Strain characteristics

Table 1 shows the serogroup distribution of carriage isolates obtained in studies from the meningitis belt, in which a cross-section of age-groups was studied. The most important pathogenic N meningitidis serogroup in sub-Saharan Africa is serogroup A, although serogroup C and more recently serogroups W135 and X have been implicated in disease outbreaks. The serogroups found in carriage strains are more diverse, with groups B, Y, 29E, Z, and non-groupable strains being detected in addition to the recognised pathogenic serogroups. The proportion of carriage strains that are serogroup A varies from 0% to 31% (table 1). Strains collected in Burkina Faso in the 1970s and 1980s have recently been reanalysed at the Pasteur Institute, and discrepancies between the reported serogroup and that determined on retesting were found (Jean-Michel Alonso, Institut Pasteur, Paris, France, personal communication). Serogrouping results from earlier carriage studies must therefore be viewed with caution.

Only a few studies used additional serological or molecular typing to distinguish between different strains that vary in their potential for transmission and invasion. The use of molecular characterisation (particularly multilocus sequence typing) in more recent studies has provided important additional insights. For example, in northern Ghana, although 18% of the strains were identified as non-groupable using standard serogrouping, most of these were unencapsulated variants of the dominating pathogenic strains circulating simultaneously. Since capsule production can be switched on and off, these variants have the potential to revert back to their capsulated form and thus become capable of causing disease. Molecular typing over 8 years in Ghana has also shown that there were three sequential waves of colonisation involving two unrelated serogroup A strains (identified as ST5 and ST7) and one serogroup X strain (ST75). Since capsule production can be switched on and off, these variants have the potential to revert back to their capsulated form and thus become capable of causing disease. Molecular typing over 8 years in Ghana has also shown that there were three sequential waves of colonisation involving two unrelated serogroup A strains (identified as ST5 and ST7) and one serogroup X strain (ST75).

Age

Figure 1 shows the age distribution of meningococcal carriage in several different studies, and illustrates that age-specific carriage patterns are not consistent throughout.

![Table 1](http://infection.thelancet.com Vol 7 December 2007)

<table>
<thead>
<tr>
<th>Year of data collection (Malta)</th>
<th>Location</th>
<th>Prevalence of carriage (%)</th>
<th>Serogroup distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>Mali</td>
<td>15/2581 (6.2%)</td>
<td>27% B 9% C 1% D 1% E 9% F 4% G 51% H</td>
</tr>
<tr>
<td>Etienne and Peraud (1972)</td>
<td>Burkina Faso</td>
<td>10/481 (7.3%)</td>
<td>31% B 32% C 8% D 1% E 15% F 1% G 1% H</td>
</tr>
<tr>
<td>Etienne and Albert (1972-73)</td>
<td>Burkina Faso</td>
<td>42/2311 (13.8%)</td>
<td>27% B 18% C 11% D 1% E 44% F 1% G 1% H</td>
</tr>
<tr>
<td>Rieu et al. (1973-77)</td>
<td>Burkina Faso</td>
<td>282/282 (100%)</td>
<td>24% B 21% C 12% D 1% E 1% F 15% G 1% H</td>
</tr>
<tr>
<td>Blakebrough et al. (1976-77)</td>
<td>Northern Nigeria</td>
<td>72/2049 (3.5)</td>
<td>14% B 1% C 18% D 7% E 1% F 22% G 1% H</td>
</tr>
<tr>
<td>Gugnani and Liganbo (1980-81)</td>
<td>Northern Nigeria</td>
<td>78/502 (15.5%)</td>
<td>1% B 2% C 6% D 5% E 16% F 1% G 1% H</td>
</tr>
<tr>
<td>Emelu et al. (1999-92)</td>
<td>Northern Nigeria</td>
<td>45/736 (6.2%)</td>
<td>18% B 36% C 11% D 2% E 24% F 1% G 1% H</td>
</tr>
<tr>
<td>Maclean et al. (1996)</td>
<td>Gambia</td>
<td>43/510 (8.4%)</td>
<td>7% B 2% C 1% D 2% E 65% F 1% G 1% H</td>
</tr>
<tr>
<td>Gagneux et al. (1998-2000)</td>
<td>Northern Ghana</td>
<td>110/1497 (7.3%)</td>
<td>15% B 1% C 14% D 1% E 1% F 4% G 1% H</td>
</tr>
<tr>
<td>Raghunathan et al. (2002)</td>
<td>Burkina Faso</td>
<td>203/892 (22.6%)</td>
<td>1% B 1% C 64% D 6% E 28% F 1% G 1% H</td>
</tr>
<tr>
<td>Mueller et al. and Varela et al. (2003)</td>
<td>Burkina Faso</td>
<td>152/3389 (6.4%)</td>
<td>18% B 3% C 2% D 1% E 1% F 1% G 1% H</td>
</tr>
<tr>
<td>Forgor et al. (2003-04)</td>
<td>Northern Ghana</td>
<td>66/609 (11.2%)</td>
<td>8% B 1% C 54% D 5% E 23% F 1% G 1% H</td>
</tr>
<tr>
<td>Amadou et al. and Nicolas (2003)</td>
<td>Niamey, Niger</td>
<td>59/836 (11.6%)</td>
<td>1% B 1% C 35% D 8% E 1% F 1% G 1% H</td>
</tr>
<tr>
<td>Boixier et al. (2003)</td>
<td>Niger</td>
<td>28/80 (35.0%)</td>
<td>18% B 1% C 2% D 53% E 1% F 1% G 1% H</td>
</tr>
<tr>
<td>Leimkugel et al. (1998-2005)</td>
<td>Northern Ghana</td>
<td>39/4999 (6.1%)</td>
<td>18% B 1% C 2% D 53% E 1% F 1% G 1% H</td>
</tr>
</tbody>
</table>

Burkina Faso was formerly known as Upper Volta. NG = non-groupable. WHO not reported. In both of Etienne and colleagues’ studies, only serogroups A, B, C were tested for. 1Studies collected in these studies were retested at the Pasteur Institute in 2006 and discrepancies were found between the reported serogroup and that found on retesting. (Jean-Michel Alonso, Institut Pasteur, Paris, France, personal communication). 2Results of longitudinal cross-sectional studies have been pooled across all timepoints. 3Carriage prevalence was studied in three towns in Nigeria, only one of which was inside the meningitis belt. 4Combined percentage of all other serogroups apart from A, B, C, D, and non-groupable reported as 90%. 5Epidemic and non-epidemic villages combined.

Table 1: Summary of the serogroup distribution of N meningitidis isolated from carriers in the African meningitis belt.
the meningitis belt. Two studies in northern Nigeria found that *N meningitidis* carriage was highest in children under 10 years of age and declined in teenagers. One of these studies also found that carriage was higher in adults aged 30 years or more than in teenagers aged 15–19 years. In northern Ghana, carriage increased to a maximum in teenagers and then declined. Meningococcal carriage is common in young children in meningitis belt countries. In both Mali and northern Nigeria, carriage was highest in the 1–4 year age group, with prevalences of 11–6% (20 of 173 children) and 14% (11 of 81 children), respectively. Few studies report specifically on carriage in children aged less than 1 year of age. Carriage was found in one of six infants in Ghana, none of 26 infants in Nigeria, and in four of 60 infants in Mali, an overall carriage rate of 5.4%. It should be noted that sample sizes in these studies were modest, and that 95% CIs (not shown in figure 1) around the point prevalence estimates in each age group are wide.

In Europe and North America, meningococcal carriage is rare in infancy and early childhood, rises to a peak in late adolescence, and then declines slowly through adult life. In the UK, the high prevalence of carriage observed in teenagers has been linked to social behaviour rather than age or sex. Given that the social norms are likely to be very different in the African meningitis belt (and with much variation within this region), it is not surprising that the European age distribution of meningococcal carriage does not appear to be replicated in these communities.

It is of interest to consider the age distribution of meningococcal carriers in relation to the age distribution of meningococcal disease cases, although this information is rarely collected in the same setting. In the meningitis belt, the peak age incidence of meningococcal disease varies from place to place and from epidemic to epidemic. The attack rate was highest among 1–4-year-olds in Ghana in 1973 and in The Gambia in 1982–83. In Nigeria in 1977, the highest incidence of meningococcal disease was among 5–9-year-olds, whereas incidence was highest among 1–4-year-olds in Burkina Faso in 1979 and in 0–4-year-olds in the Sudan and Niger in 1988.

There are few studies that have described the epidemiology of endemic meningococcal disease. In Niger, the proportion of group A meningococcal meningitis cases in under 5-year-olds was higher in epidemic than non-epidemic years (p < 0.03). In northern Nigeria in 1977, the age incidence of meningococcal carriage and invasive disease was studied simultaneously; the peak age incidence of disease cases was in those aged 5–9 years, whereas carriage was distributed more evenly in children and young adults.

**Sex**

Most studies that reported sex differences in carriage did not find a significant difference between men and women, with one exception. However, in a study of household contacts of meningococcal disease in Nigeria, although the overall prevalence of carriage was not influenced by sex, the prevalence of carriage in those aged under 20 years was significantly higher in men than women (p < 0.02). Furthermore, the reverse was found in those aged 20 years or older, with prevalence of carriage being significantly higher in women than men (p < 0.01; figure 2), perhaps reflecting differences in social patterns between men and women in this traditional Muslim society.

**Contact with a case**

Several studies have investigated carriage rates in contacts of individuals with meningococcal disease. These studies have all shown that carriage of the pathogenic serogroup was significantly higher in the immediate family group compared with all household contacts (p < 0.001) and that there was a significantly higher carrier rate among individuals sleeping in the same room as disease cases compared with other household members (p < 0.024).
Presence of other Neisseria spp

Three studies have specifically measured carriage of *N. lactamica* as well as that of *N. meningitidis*.[8,9,12-14] Carriage of *N. lactamica* was high in younger children in the meningitis belt, consistent with findings elsewhere. The prevalence of *N. lactamica* carriage also varied over time in the northern Ghana study (April, 1998 to November, 2005) with a maximum of 9.7% (in November, 1999) and a minimum of 0.3% (in April, 2005).[6] There is little evidence to support the hypothesis that carriage of *N. lactamica* protects against carriage of *N. meningitidis.* In northern Nigeria the frequency of dual carriage of meningococci and *N. lactamica* was not significantly different from that which would be expected by chance.[15] In northern Ghana the prevalence of co-colonisation with *N. lactamica* and *N. meningitidis* was lower than expected (p=0.02), but there was no association between carriage of *N. lactamica* and acquisition of serogroup X meningococci either at the individual or community level.[16]

Duration of carriage

Only one study has estimated the duration of *N. meningitidis* carriage in the African meningitis belt,[17] this study suggested that the half-life of carriage was about 3 months and similar to that of carriage with *N. lactamica*. In Niger, it was reported that five individuals carried indistinguishable W135 strains in two consecutive studies 10 months apart, suggesting that long-term carriage may occur.[18] It is likely that the duration of carriage varies by strain and according to the age of the host, but there is no evidence to support or refute this from studies in the meningitis belt.

Season

Epidemics of meningococcal disease occur in the African meningitis belt during the dry season. Although few longitudinal or serial cross-sectional studies have been done, the limited information available, summarised in table 2, does not suggest that there is an association between carriage rate and season.[19,20,22,23] Additionally, no significant association between carriage and season was found in an area of eastern Nigeria just outside the meningitis belt.[24]

The season in which a new strain is introduced into a community may be important in determining whether a disease outbreak occurs (providing other epidemic conditions are satisfied). A study in a village in northern Nigeria showed that acquisition of serogroup A meningococci by several members of the community during the rainy season was not associated with an outbreak of meningitis, but the number of participants in this study was small.[9]

Epidemic/endemic situation

The limited data available do not suggest any clear relation between the prevalence of *N. meningitidis* carriage and the incidence of disease; a wide range of carriage prevalences have been reported in both epidemic and endemic situations. For example, during an epidemic in northern Nigeria it was reported that only 3.8% of 1098 household contacts and 2.6% of 416 controls (non-contacts) carried serogroup A meningococci.[25] In other epidemic situations, the prevalence of carriage of the epidemic strain has been much higher, reaching 25% in a serogroup A epidemic in The Gambia.[10] 25% during a W135 epidemic in Burkina Faso,[18] 18% during an outbreak of serogroup X in Ghana,[26] and 18% during a W135 outbreak in Ghana.[27] The prevalence of carriage in non-epidemic situations is readily variable, ranging from 3% to 27% (all serogroups),[8,25] with several studies reporting a point prevalence of 6-8%.[8,12,13,26]

Comparisons between epidemic and non-epidemic areas at the same time may reveal important differences in the distribution of pathogenic strains. A study in Burkina Faso[18] found an overall meningococcal carriage of 27.8% (in 460 individuals) in an area that was experiencing an outbreak of W135 meningitis compared with a rate of 12.1% (in 439 individuals) in a non-epidemic district; the prevalence of serogroup W135 was 25.2% (90.6% of all carriage) in the epidemic district but only 3.4% (20% of...
all carriage) in the non-epidemic district. Although not all isolates were typed further (using multilocus enzyme electrophoresis), it appeared that ET37 strains (designated as ST11 by multilocus sequence typing) dominated. This dominance of one particular strain may be a more important marker of epidemic conditions than overall prevalence, but more studies with fine typing of isolates are required.

Vaccination

Only six studies have investigated the effect of vaccination with polysaccharide vaccines on meningococcal carriage in Africa (Table 3). Only one study, which was done in Egypt, reported a significant effect of vaccination on carriage in case contacts. No studies have investigated the impact of vaccination on density or duration of carriage. Safety and immunogenicity studies of conjugate vaccines in Africa have so far been too small to allow an effect on meningococcal carriage to be investigated.

Dynamics of meningococcal carriage

Longitudinal studies are required to determine the dynamics of *N meningitidis* carriage. Factors that may be important in the appearance and disappearance of particular strains include the transmissibility of the strain, the duration of carriage, the development of immunity, and chance effects. Few longitudinal studies of carriage have been done in Africa. In northern Nigeria, the appearance and disappearance of the group A meningococcus was observed over a period of 8 months. In northern Ghana, meningococcal carriage studies have been done every 6 months since 1998 by the Navrongo Health Research Centre and collaborators. Carriage data collected over this period support the hypothesis that different meningococcal strains invade, spread, and wane with specific populations in successive waves.

Seroprevalence studies

Pharyngeal carriage of *N meningitidis* can induce naturally acquired immunity to meningococci. Seroprevalence studies are thus an additional means of measuring the patterns of exposure to meningococci. Few seroprevalence studies have been done in Africa. In northern Nigeria, the prevalence of participants with a titre of haemagglutinating antibody to serogroup A meningococcal polysaccharide 1.8 or more was found to be low in individuals less than 2 years. The prevalence then increases sharply in individuals aged 2-4 years and then rises more slowly, peaking in older children and young adults. A study in Burkina Faso in 2003 showed that serogroup A antibody concentrations, assessed by both bactericidal antibody and ELISA measurements, increased with age and reached a peak in those aged 19-23 years, probably caused in part by previous vaccination. Antibodies to group W135 meningococci were low in all age-groups, suggesting little previous exposure to this strain. This study found no association between W135 antibody concentration and carriage, by contrast with studies done elsewhere in Burkina Faso in 2002 and in Niger in 2003.

Conclusions

A few tentative conclusions can be drawn from the results of this Review of meningococcal carriage in the African meningitis belt. Carriage of *N meningitidis* is not necessarily rare in interepidemic periods and carriage strains are more diverse than disease-causing strains—for example, carriage of serogroup B meningococci is sometimes found even though this bacterial strain rarely causes disease. Patterns of carriage by age are not consistent across studies, probably because transmission is affected by behavioural and social factors that vary across the meningitis belt. In general, compared with Europe, young children and older adults carry meningococci more frequently. Changes in the prevalence of carriage are not linked to season in any consistent way; this supports the hypothesis that epidemics

<table>
<thead>
<tr>
<th>Year of data collection</th>
<th>Location</th>
<th>Number of people tested for carriage</th>
<th>Effect of vaccine on serogroup A carriage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garshon et al**</td>
<td>1971</td>
<td>Northern Nigeria</td>
<td>595 vaccinated, 589 controls</td>
</tr>
<tr>
<td>Warden et al³</td>
<td>1973</td>
<td>Egypt</td>
<td>1191 vaccinated, 1178 controls</td>
</tr>
<tr>
<td>Greenwood et al⁴</td>
<td>1977</td>
<td>Nigeria</td>
<td>431 vaccinated, 450 controls</td>
</tr>
<tr>
<td>Brewins et al⁵</td>
<td>1978</td>
<td>Rwanda</td>
<td>153 vaccinated, no controls</td>
</tr>
<tr>
<td>Wildbrough et al⁶</td>
<td>1978</td>
<td>Northern Nigeria</td>
<td>85 vaccinated, 83 controls</td>
</tr>
<tr>
<td>Harris-King et al⁷</td>
<td>1983-84</td>
<td>Gambia</td>
<td>100 prevaccv, 250 tested 6 months after vaccine, 500 tested 18 months after vaccine</td>
</tr>
</tbody>
</table>

*These vaccines used in this study failed to protect recipients against meningococcal disease and therefore is of doubtful potency. **Trial location outside the meningitis belt. ³Fistula toe trial vaccine given to controls.

Table 3: Summary of studies that examined the impact of serogroup A polysaccharide vaccines on serogroup A carriage in Africa.
of meningococcal disease occur in the dry season because of a change in the case to carrier ratio rather than as a result of increased transmission. No consistent association has been found between the overall prevalence of carriage and disease, although the dominance of a pathogenic strain in carriers may be a useful marker of epidemic conditions. The use of molecular characterisation in carriage studies is an important advance and has helped to further our understanding of carriage dynamics. Although few studies have employed these techniques to date, the use of such methods should be encouraged in future studies.

The development of conjugate vaccines offers new prospects for controlling meningococcal disease in the African meningitis belt. The Meningitis Vaccine Project is a partnership between PATH and WHO that aims to develop, produce, and introduce affordable group A conjugate vaccines in Africa;17 phase I and II trials have been successfully completed and a demonstration project is expected to start in 2008. A heptavalent combination vaccine (group A and C meningococcal conjugate combined with diphtheria, tetanus, and whole-cell pertussis, Haemophilus influenzae type b, and hepatitis B) for use in infant schedules has been developed by GlaxoSmithKline. Following meningococcal serogroup C conjugate vaccination in the UK (in 0–24-years-olds) and the Netherlands (in 1–19-years-olds), serogroup C carriage was reduced,18 resulting in the generation of substantial herd immunity. If meningococcal conjugate vaccines are to be equally effective in Africa, it is essential that they reduce pharyngeal carriage and interrupt transmission. The ability of group A conjugate vaccines to reduce carriage has yet to be shown and carefully designed studies are required to measure their impact on carriage and transmission in the African meningitis belt. Additionally, knowledge of meningococcal transmission dynamics can assist with the rational design and targeting of vaccination strategies. To maximise the public-health impact of serogroup A conjugate vaccines, immunisation needs to be targeted at the groups who constitute the largest reservoir of infection—for example, meningococcal serogroup C conjugate vaccine campaigns in the UK and the Netherlands targeted teenagers, in whom meningococcal carriage and transmission was most common. The limited data available from the studies included in this Review are not sufficient to indicate definitively who these groups are in the African meningitis belt, and further carriage studies would be helpful to guide the most effective deployment of the vaccines currently under development. Careful monitoring of the strain composition of both carriage and disease isolates will also be required following the introduction of conjugate vaccines.

Conflicts of Interest
We declare that we have no conflicts of interest.

Acknowledgments
We thank Monique Berliere (Meningitis Vaccine Project) for doing the initial literature search. We also thank the participants of the WHO meningococcal carriage workshop for helpful discussions (http://www.who.int/vaccine_research/diseases/maeningitis/Consultation_Meningococcal_Carriage_230905.pdf).

References

Search strategy and selection criteria
We identified original papers and reports on meningococcal carriage studies in Africa published before July, 2007, by searching PubMed, Medline, and Web of Science databases using the keywords “meningococcal” or “Neisseria” and “carriage” and “Africa.” We also reviewed the citations of retrieved papers, reports, and theses, searched our own files, and asked expert colleagues if they knew of further studies. No language restrictions were imposed, but all the retrieved papers were in English or French. We categorised the studies according to time period and by location (within or outside the meningitis belt).