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Original article

Oropharyngeal carriage of potential meningitis-causing bacteria in a Ghanaian prison

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ABSTRACT

Background: Bacterial meningitis continues to be a global health problem even after introducing of meningococcal and pneumococcal vaccines. Surveillance of high-risk populations such as prisoners is necessary for timely identification of outbreaks and prophylaxis. This study assessed pharyngeal colonisation of prisoners and officers in a Ghanaian prison with meningitis-causing bacteria. **Methods:** A cross-sectional study was conducted from January to April 2018. Oropharyngeal swabs were collected, and microbiological and antimicrobial susceptibility analyses were performed. **Results:** There were 205 participants. Carriage of meningitis-causing bacterial was 102 (49.7%), 8 (3.9%) and 1(0.48%) for *Neisseria species (spp.)*, *Staphylococcus aureus (S. aureus*) and *Streptococcus pneumoniae (S. pneumoniae),* respectively and with a total carriage of 52.2% (107/ 205). Four individuals (1.9%) carried both *Neisseria spp.* and *S. aureus.* The *S. aureus* isolates were resistant to ampicillin (87.5%), chloramphenicol (87.5%), and penicillin (87.5%) and sensitive to cefoxitin (100%) cotrimoxazole (87.5%), clindamycin (87.5%), ciprofloxacin (75.0%), oxacillin (75.0%), and erythromycin (62.5%). None of the *S. aureus* isolated was methicillin resistant. The *S. pneumoniae* isolated was resistant to cotrimoxazole, tetracycline, and penicillin and sensitive to chloramphenicol, erythromycin, and clindamycin. Education (OR = 1.910, 95% CI 1.029 – 3.545, p = 0.040) and years of incarceration (OR = 3.808, 95% CI 1.350 – 10.739, p = 0.011) were associated with carriage of meningitis-causing bacteria. **Conclusion:** This study showed carriage of potential meningitis-causing bacteria in a Ghanaian prison. Multivalent meningococcal conjugate vaccine is key to controlling meningococcal disease outbreaks.

Introduction

Bacterial meningitis is an infectious disease characterized by inflammation of the meninges [1,2]. Bacterial meningitis remains a global health problem with high morbidity and mortality. Bacterial meningitis sequelae are such as brain damage, cognitive impairment, and hearing loss [3]. Aetiology of bacterial meningitis varies across age groups and geographic locations. Among

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adults, this infection is usually caused by *Neisseria meningitidis*, *Streptococcus pneumoniae*, and *Haemophilus influenzae* type b (Hib) [4]. The infection is reported to affect about 26 countries in what is known as 'the meningitis belt' in sub-Saharan Africa particularly among children and the aged persons [5]. An epidemiological survey of bacterial meningitis in five countries in the meningitis belt in the subregion over 18,000 suspected cases between 2015 – 2017, with an annual prevalence 0.3 – 7.5% [4].

Preventive measures such as the introduction of pneumococcal conjugate and meningococcal vaccines have led to a considerable decline in meningitis incidence [4]. In the meningitis belt, *N. meningitidis* serogroup A used to be notorious for outbreaks until the introduction of the meningococcal serogroup A conjugate vaccine (MACV, MenAfriVac) in 2010. However, recent outbreaks and surveys show the emergence of serogroups C and W [6,7]. This calls for the deployment of a multivalent meningococcal conjugate vaccine in controlling meningococcal meningitis among high-risk populations [4].

Asymptomatic colonization of the nasopharynx has been identified as the most important prerequisite for subsequent invasive disease for several bacterial pathogens, including meningococci and pneumococci diseases [8,9]. However, studies have shown that meningococcal carriage is complex and highly dynamic [10,11]. Carriage of these pathogens, low relative humidity (dry season), high aerosol load, and underlying conditions are associated with meningitis [12,13]. To date, little colonization data are available among high-risk populations such as children, aged persons, boarding schools, and correctional facilities apart from outbreaks and feasibility assessments after the introduction of meningococcal serogroup A vaccine in the meningitis belt.

Previous studies in prisons provide evidence that infectious diseases such as tuberculosis and bacterial meningitis are transmitted to individuals while incarcerated [14]. This is a concern not only to prisoners but also to public health [15,16]. Close living quarters, overcrowding, sharing of personal items, rationing and restricted access to water and toiletries, and substance abuse in prisons in developing countries such as Ghana increase the risk of bacterial meningitis and other infection. Against this backdrop, this study sought to assess the carriage of potential meningitis-causing bacteria amongst prisoners and officers in a Ghanaian prison.

Materials and methods

Study design and population

This was a cross-sectional study conducted in a Ghanaian prison from January to April 2018. The facility, was wielded with overcrowding and poor sanitation, houses more than 1900 inmates: more than twice its original capacity of 700.

Sampling technique

A total of 205 individuals were recruited, of which 184 were inmates and 21 officers. Per the working regulation at the facility at the time of recruitment, participants were conveniently selected with assistance from prison officers after the study protocol was explained to them. Participants were selected from all available cells to give homogeneity to the sample. A structured questionnaire was used to obtain socio-demographic data and clinical data on recent illness and antibiotic usage.

Samples/ data collection

Oropharyngeal specimen was collected from each participant using Eswab® (COPAN Diagnostics Inc., Italy LOT 202430900). Oropharyngeal swabs were collected by trained laboratory personnel with participants seated and having their heads tilted backward, samples were taken directly from the back of the throat carefully, without touching the teeth, cheeks, gum, or tongue when inserting and removing the swab. The swabs were left in place for about two seconds and then gently rotated through 180 degrees around and behind their tonsils before removal. Ulcerated or inflamed and white patches in the tonsillar areas were sampled. Samples were kept in the transport media that come with the swabs, placed in a biohazard specimen bag, and immediately transported to the microbiology laboratory at the Kumasi Centre for Collaborative Research (KCCR), KNUST, Kumasi.

Bacterial isolation

The swabs were streaked directly onto colistin and nalidixic acid (CNA) agar supplemented with 5% sheep blood and modified Thayer Martin (Difco, Beckton Dickinson, USA) agar for the isolation of *S. pneumoniae* and *S. aureus*, and *Neisseria species*, respectively. The plates were incubated in a 5% CO_2 incubator at 35-37^{o}C for 18-24 h.

Colonies on CAN agar that were morphologically consistent with *S. pneumoniae* and s aureus were

gram stained. Alpha-haemolytic streptococcus colonies were tested for *S. pneumoniae* using the Optochin diffusion disc method. Presumptive *S. aureus* colonies were confirmed using coagulase agglutination method using rabbit plasma. Presumptive Neisseria colonies were sub-cultured on blood agar and preliminary identified using oxidase and Gram-staining. Oxidase-positive and catalase-positive gram-negative diplococci were presumptive of *Neisseria spp.*

Antimicrobial susceptibility tests

Antibiotic susceptibility testing was done using the Kirby-Bauer disk diffusion method and the zones of inhibition were interpreted according to the CLSI (2015) guidelines. For *S. pneumoniae* antibiotic susceptibility testing was done on 5% sheep blood Mueller-Hinton agar (Oxoid) and that of *S. aureus* was done on only Muller-Hinton (Oxoid). The choice of antibiotics used was based on Clinical and Laboratory Standard Institute guidelines. Antibiotic Disc Concentrations Used (Oxoid, Basingstoke, England) as shown in **table (1)**.

Statistical Analysis

Descriptive statistics was used to present categorical variables as frequencies and percentiles and mean (SD) for continuous variables. Logistic regression analysis was used to determine factors that associate with carriage of meningitis-causing bacteria. All data acquired were entered using Epi info® version 7.2.2.6 by CDC and analysed using IBM SPSS 26.0.

Ethical consideration

Ethical approval for this study was obtained from the Committee on Human Research and Publication Ethics at the KNUST School of Medicine and Dentistry and the Komfo Anokye Teaching Hospital, Kumasi, with approval number CHRPE/AP/577/17. In addition, institutional approval was obtained from the Ghana Prisons Service Headquarters, Accra, and informed consent obtained from all participants. This study was carried out in accordance with the Declaration of Helsinki.

Results

Participants' characteristics

Of the 205 included individuals, 184 were inmates and 21 officers. The mean age of the study participants was 27.6±7.1 with most of the participants, 79 (38.5%), between the ages of 18 to 23 years. There were 199 (97.1%) males. Two-thirds of the participants, 136 (66.3%), had up to only basic education and 179 (87.3%) had been in incarceration or worked in the prison for less than five years. A little more than half of the participants, 109 (53.2%), had no prior knowledge of meningitis and none reported of a past infection. Of the total, only 5 (2.4%) had been vaccinated against meningitis. More than a third of the participants, 72 (35.1%), reported of elevated body temperature in the past 30 days and more than half, 109 (53.2%), reported meningitis-related symptoms. Antibiotic usage was reported by 38 (18.5%) of the study participants. **Table 2** below summarises these participants characteristics and medical history.

Carriage and distribution of potential meningitis-causing bacteria

Carriage of potential meningitis-causing bacteria was identified in 107 (52.2%) of the study participants, with 102 (95.62%), 8 (3.90%) and 1(0.48%) positive for *Neisseria spp.*, *S. aureus* and *S. pneumoniae*, respectively **(Figure 1).** There was multiple carriage of potential meningitis-causing bacteria: four individuals (1.9%) were positive for both *Neisseria spp.* and *S. aureus*.

Factors associated with carriage of meningitis-causing bacteria

Following the estimation of the carriage of meningitis causing bacteria, we sought to identify the factors associated. **Table 3** below summarises the associations with carriage. Post-basic education (OR = 2.238, 95% CI = 1.229 – 4.075, p = 0.008) and at least five years of incarceration (OR = 4.542, 95% CI = 1.640 – 12.576, p = 0.004) were significantly associated with carriage.

Education level and years of incarceration are associated with carriage of meningitis-causing bacteria

To validate the factors associated with carriage of the potential meningitis-causing bacteria, a multivariate logistic regression analysis (MLGA) was performed. Here, the MLGA was done using the significant associations, that is, education and years of incarceration. The model was significant compared to the null model ($\chi^2(2) = 14.728$, p = 0.001) and explain 9.2% of the variation in carriage (Nagelkerke R^2) shown in table 4 below. Individuals with post-secondary education were nearly twice as likely to carry potential meningitis-causing bacteria (OR = 1.910, 95% CI 1.029 – 3 545) compared to those with up to basic education, and individuals who had been in incarceration for at least five years were nearly four times likely to carry meningitis-causing bacteria (OR = 3.808, 95% CI 1.350 –

10.739) compared to individuals that have been in incarceration for less than five years.

Antimicrobial susceptibility tests (AST)

Considering the increase in antimicrobial resistance, only *S. aureus* and *S. pneumoniae* isolates were subjected to AST due to limited logistics. Antimicrobial tests showed that isolated *S. aureus* were largely resistant to Ampicillin, Chloramphenicol, and Penicillin. The isolates were mostly sensitive to Cefoxitin, Clindamycin, Cotrimoxazole, Ciprofloxacin, Ofloxacin, and Erythromycin. There was no methicillin resistant *S. aureus* (MRSA) isolated. The *S. pneumoniae* isolated was sensitive to Chloramphenicol, Erythromycin and Clindamycin and resistant to Cotrimoxazole, Tetracycline and Penicillin. Table 5 summarises the antimicrobial trends in this study. Positive control bacteria strains were obtained from the microbiome study group at KCCR, KNUST. for validation of isolates and antimicrobial susceptibility tests.

Table 1. Antibiotic disc concentrations used (Oxoid, Basingstoke, England)

Bacteria	**Antibiotic**	**Concentration (µg/disc)**
S. aureus	Ampicillin	10
	Chloramphenicol	30
	Ciprofloxacin	5
	Cotrimoxazole	25
	Erythromycin	15
	Penicillin	1
	Clindamycin	2
	Oxacillin	1
	Cefoxitin	30
	Clindamycin	2
	Ofloxacin	
S. pneumoniae	Chloramphenicol	30
	Cotrimoxazole	25
	Erythromycin	15
	Tetracycline	30
	Penicillin	1
	Clindamycin	2

Table 2. Participants' characteristics and medical history

Variable		**n (%)**	***p*-value**
Age	Mean (SD)	27.6 (7.1)	NA
Age groups	18-23	79 (38.5)	< 0.001
	24-29	55 (26.8)	
	30-35	24 (11.7)	
	>35	47 (22.9)	
Gender	Male	199 (97.1)	< 0.001
	Female	6 (2.9)	
Education background	Basic	136 (66.3)	< 0.001
	Post-basic	69 (33.7)	
Years of incarceration	< 5 years	179 (87.3)	< 0.001
	≥ 5 years	26 (12.7)	
Knowledge of meningitis	Yes	96 (46.8)	0.402
	No	109 (53.2)	
Prior meningitis	Yes	0 (0.0)	N/A
	No	205 (100.0)	
Vaccination status	Yes	5 (2.4)	< 0.001
	No	200 (97.6)	
Fever in the past 30 days	Yes	72 (35.1)	< 0.001
	No	133 (64.9)	
Symptoms of meningitis	Yes	109 (53.2)	0.402
	No	96 (46.8)	
Antibiotic usage	Yes	38 (18.5)	< 0.001
	No	167 (81.5)	

Table 3. Univariate logistic regression model for factors that associate with carriage of potential meningitis-causing bacteria.

Covariate		**n**	**OR**	**95% CI**	***p*-value**
Age groups	**(18 – 23 years)**	79	**(Ref)**	**(Ref)**	**(Ref)**
	24 – 29 years	55	1.66	0.83 – 3.33	0.152
	30 – 35 years	24	1.19	0.48 – 2.98	0.703
	above 35 years	47	1.61	0.78 – 3.34	0.199
Gender	**Male**	199	**(Ref)**	**(Ref)**	**(Ref)**
	Female	6	1.86	0.33 – 10.41	0.478
Knowledge of Meningitis	**No**	109	**(Ref)**	**(Ref)**	**(Ref)**
	Yes	96	1.16	0.67 – 2.01	0.596
Symptoms	**No**	96	**(Ref)**	**(Ref)**	**(Ref)**
	Yes	109	0.74	0.42 – 1.28	0.276
Antibiotic Treatment	**No**	167	**(Ref)**	**(Ref)**	**(Ref)**
	Yes	38	1.74	0.84 – 3.58	0.137
Education	**Basic**	136	**(Ref)**	**(Ref)**	**(Ref)**
	Post-basic	69	2.24	1.23 – 4.08	0.008
Incarceration Period	**Less than five years**	179	**(Ref)**	**(Ref)**	**(Ref)**
	At least five years	26	4.54	1.64 – 12.58	0.004

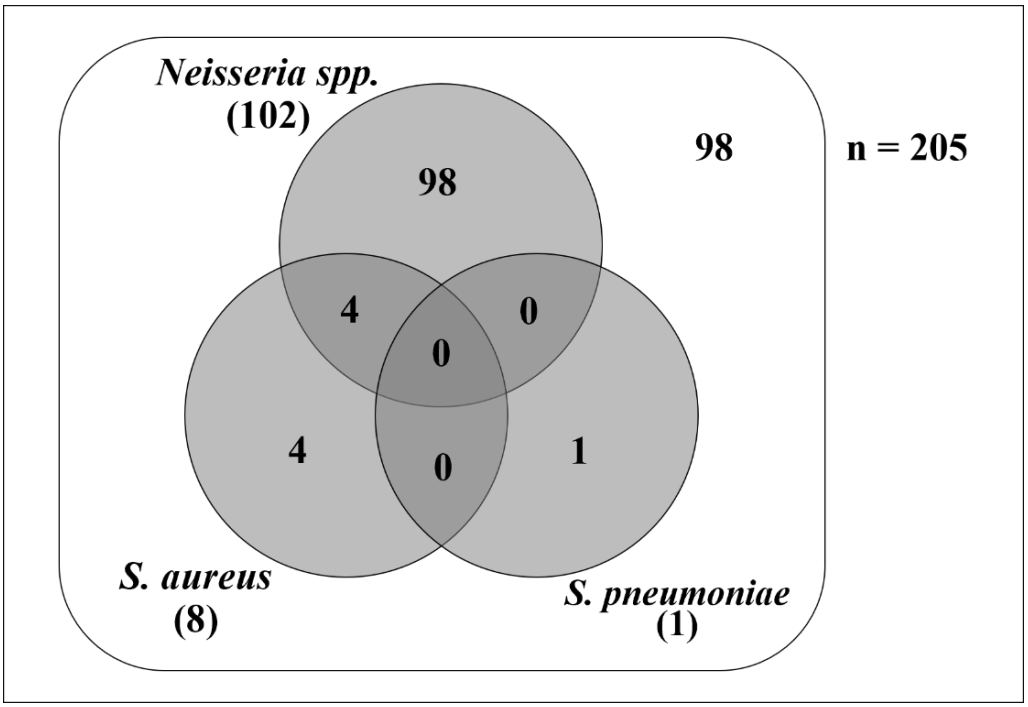
Table 4. Multivariate logistic regression model for factors that associate with carriage of meningitis-causing bacteria.

Independent variable		**n**	**Model χ^2 (df)**	***p*-value**	**Psuedo-R^2**	**OR**	**95% CI**	***p*-value**
			14.728 (2)	0.001	.092			
Education	**Basic**	136				(Ref)	(Ref)	(Ref)
	Post-basic	69				1.91	1.03 – 3.55	0.040
Incarceration Period	**(< five year)**	179				(Ref)	(Ref)	(Ref)
	≥ five years	26				3.81	1.35 – 10.74	0.011

Table 5. Antimicrobial susceptibility tests

Bacteria	**Antibiotic**	**Sensitivity**
		Sensitive
S. aureus	Ampicillin	2 (25%)
	Chloramphenicol	4 (50%)
	Ciprofloxacin	6 (75.0%)
	Cotrimoxazole	7 (87.5%)
	Erythromycin	5 (62.5%)
	Penicillin	2 (25%)
	Clindamycin	7 (87.5%)
	Oxacillin	6 (75.0%)
	Cefoxitin	8 (100%)
	Clindamycin	4 (50%)
S. pneumoniae	Chloramphenicol	1 (100%)
	Cotrimoxazole	0 (0.0%)
	Erythromycin	1(100%)
	Tetracycline	0 (0.0%)
	Penicillin	0 (0.0%)
	Clindamycin	1 (100%)

Figure 1. Carriage of potential meningitis-causing bacteria among the study participant. More than half, 52.2% of the participants carried at least one of *Neisseria spp.*, *S. aureus* or *S. pneumoniae*.



Discussion

Growing evidence suggests the expansion of the bacterial aetiology of meningitis in sub-Saharan Africa despite the success chalked after the introduction of the pneumococcal and meningococcal vaccination programs [6]. Considering the geographic and age group disparities of bacterial meningitis across the world, frequent surveillance of at-risk populations is essential for tailored strategies in reducing the burden of meningitis. In light of this, our study screened male inmates and officers in a Ghanaian prison, following suspected and sporadic outbreaks in the country in 2016 and 2017 [5]. In general, healthcare delivery in prisons in developing countries are deplorable, as infirmaries are usually underequipped.

In as much as specific *Neisseria* species were not identified in this study, recent studies have pointed out the role of *Neisseria* commensal in conferring virulence in *N. meningitidis* through horizontal genetic transfer (HGT). Clemence *et al.* [17] showed in their study that polysaccharide capsule genes, previously thought to be unique to meningococci, are present in non-pathogenic *Neisseria*. Furthermore, Calder *et al.* [18] in their study reported the presence of numerous 'virulence genes' within the commensal species. Virulence factors in these non-pathogenic commensals are likely to contribute to the burden of meningococcal disease as HGT has been shown to be responsible for uptake by meningococcal species. In addition, quinolone resistance in *N. meningitidis* has been described in the same HGT fashion from three commensal *Neisseria spp.* [19].

The paucity of data on prison health especially in this part of the world makes findings of this study revealing and deserving of some attention. Carriage of potential meningitis-causing was identified in more than half, 107 (52.2%) of the participants with *Neisseria spp.* being predominant with 95.3% of total carriage. Soeters *et al.* [4] investigated the epidemiology of bacterial meningitis in the meningitis belt and found *N. meningitidis* responsible for the majority (56%) of all confirmed cases, followed by *S. pneumoniae* with 40%. The shift in carriage identified in this study needs to be further investigated to delineate the landscape of bacterial meningitis in Ghana.

While participants with post-basic education were nearly twice as likely to carry potential meningitis-causing bacteria, at least five years of incarceration was associated with nearly four times likelihood. The association with education may be inexplicable. However, prolonged stay in correctional facilities that are usually overcrowded is likely to contribute to the risk of carriage and developing disease there off [13]. Multiple carriages of meningitis-causing bacteria, *Neisseria spp.* and *S. aureus*, was present in 4 (2%) of participants. Contrary to this, Khan *et al.* [20] in their study found coagulase-negative staphylococci to be predominant among patients with bacterial meningitis. However, these commensals may be opportunistic and have been found to influence *S. aureus* colonisation and disease [21]. The relatively low prevalence of *S. pneumoniae* may point to the reduced burden of pneumococcal meningitis in Ghana.

Following the MenAfriVac program against *N. meningitidis* serogroup A, the incidence of bacterial meningitis in the meningitis belt reduced considerably [7]. However, there seems to be selective pressure for serogroups C and W in recent years as these have been implicated in sporadic outbreaks in recent years [7,22]. A retrospective study in Qatar by Hamed *et al.* [23] also identified *N. meningitidis* W_{135} as the commonest serogroup after molecular characterisation of *N. meningitidis*. Although this study only looked at the carriage of potential meningitis-causing bacteria, the outlook showed increased carriage of *Neisseria spp.* However, it important to establish that not all *Neisseria* spp. cause meningitis, since many are commensals in the oropharynx suggesting the need for further extensive molecular approaches to differentiate between commensal *Neisseria* and *Neisseria* causing meningitis.

This is of public health concern and calls for renewed and improved efforts towards multivalent meningococcal vaccine programs especially among at risk populations.

Antimicrobial tests showed high resistance of *S. aureus* to Ampicillin (87.5%), Chloramphenicol (87.5%), and Penicillin (87.5%). However, these isolates were sensitive to Cefoxitin (100%) Cotrimoxazole (87.5%), Clindamycin (87.5%), Ciprofloxacin (75.0%), Oxacillin (75.0%), and Erythromycin (62.5%). Interestingly, there was no MRSA isolated, and may be due to the relatively low antibiotic usage in the prison and the low number of isolates. The *S. pneumoniae* isolated was resistant to cotrimoxazole, tetracycline and

penicillin and sensitive to chloramphenicol, erythromycin and clindamycin. Considering the increasing burden of antimicrobial resistance, the need for deepened antibiotic stewardship cannot be overemphasised [24]. Although one may argue the restricted nature of prisons and reduced access to medication, smuggling and substance abuse is not uncommon [13]. On the other hand, and with regards to prison health, an informal interview with the health personnel at the prison infirmary revealed that healthcare within the walls relies heavily on donations.

Conclusions

This study showed high carriage of potential meningitis-causing bacteria viz: *Neisseria spp.*, *S. aureus* and *S. pneumoniae*) with multiple carriages in a Ghanaian prison. Education level and years of incarceration were associated with carriage. Bacterial meningitis remains a global challenge and in prisons where inmates live in close quarters that are overcrowded, pragmatic and proactive measures are needed to prevent outbreaks of such infectious diseases. Multivalent meningococcal conjugate vaccine is key to the prevention and control of meningococcal meningitis among at risk populations in the meningitis belt.

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Authorship

EKAA: investigation (supporting); formal analysis (lead); writing – original draft (lead); writing – review and editing (equal). CKAA: Methodology (supporting); investigation (supporting); writing – review and editing (equal). RBA: Investigation (equal); writing – review and editing (equal). AA: Investigation (equal); writing – review and editing (equal). KGB: Methodology (lead); investigation (lead); writing – review and editing (equal). AK: Conceptualization (lead); Writing – original draft (supporting); Writing – review and editing (equal).

Conflict of interest

The authors declare no competing interest.

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References

1. **Dorratoltaj N, O'Dell ML, Bordwine P, Kerkering TM, Redican KJ, Abbas KM.** Epidemiological Effectiveness and Cost of a Fungal Meningitis Outbreak Response in New River Valley, Virginia: Local Health Department and Clinical Perspectives. Disaster Med Public Health Prep 2018;12(1):38-46.
2. **Richie MB, Josephson SA.** A Practical Approach to Meningitis and Encephalitis. Semin Neurol 2015; *35*:(6): 611-620.
3. **Oordt-Speets AM, Bolijn R, van Hoorn RC, Bhavsar A, Kyaw MH.** Global etiology of bacterial meningitis: a systematic review and meta-analysis. PloS one 2018; 13:(6): e0198772.
4. **Soeters HM, Diallo AO, Bicaba BW, Kadadé G, Dembélé AY, Acyl MA, *et al.*** MenAfriNet Consortium. Bacterial Meningitis Epidemiology in Five Countries in the Meningitis Belt of Sub-Saharan Africa, 2015-2017. J Infect Dis 2019 ;220(220 Suppl 4):S165-S174.
5. **Kwarteng A, Amuasi J, Annan A, Ahuno S, Opare D, Nagel M, *et al.*** Current meningitis outbreak in Ghana: Historical perspectives and the importance of diagnostics. Acta Trop 2017; 169: 51-56.
6. **Mohammed I, Iliyasu G, Habib AG.** Emergence and control of epidemic meningococcal meningitis in sub-Saharan Africa. Pathog Glob Health 2017;111(1):1-6.
7. **Novak RT, Ronveaux O, Bita AF, Aké HF, Lessa FC, Wang X, *et al.*** Future Directions for Meningitis Surveillance and Vaccine Evaluation in the Meningitis Belt

of Sub-Saharan Africa. J Infect Dis 2019; 220:(220 Suppl 4), S279-s285.

8. **Balmer P, Burman C, Serra L, York LJ.** Impact of meningococcal vaccination on carriage and disease transmission: A review of the literature. Hum Vaccin Immunother 2018;14(5):1118-1130.
9. **Fitzgerald D, Waterer GW.** Invasive Pneumococcal and Meningococcal Disease. Infect Dis Clin North Am 2019;33(4):1125-1141.
10. **Jolley SE, Alkhafaf Q, Hough C, Welsh DA.** Presence of an Alcohol Use Disorder is Associated with Greater Pneumonia Severity in Hospitalized HIV-Infected Patients. Lung 2016;194(5):755-62.
11. **Mulhall RM, Brehony C, O'Connor L, Meyler K, Jolley KA, Bray J, *et al.*** Resolution of a Protracted Serogroup B Meningococcal Outbreak with Whole-Genome Sequencing Shows Interspecies Genetic Transfer. J Clin Microbiol 2016; 54:(12): 2891-2899.
12. **Agier L, Deroubaix A, Martiny N, Yaka P, Djibo A, Broutin H.** Seasonality of meningitis in Africa and climate forcing: aerosols stand out. J R Soc Interface 2013; 10:(79): 20120814.
13. **Sanchez GV, Bourne CL, Davidson SL, Ellis M, Feldstein LR, Fay K, *et al.*** Pneumococcal Disease Outbreak at a State Prison, Alabama, USA, September 1-October 10, 2018[1]. Emerg Infect Dis 2021;27(7):1949-1952.
14. **Sarpong AA, Otupiri E, Yeboah-Awudzi K, Osei-Yeboah J, Berchie GO, Ephraim R.** An Assessment of Female Prisoners' Perception of the Accessibility of Quality Healthcare: A Survey in the Kumasi Central Prisons, Ghana. Ann Med Health Sci Res 2015 ;5(3):179-84.
15. **Clayton JL, Miller KJ.** Professional and Regulatory Infection Control Guidelines: Collaboration to Promote Patient Safety. AORN J 2017;106(3):201-210.
16. **Kaburi BB, Kubio C, Kenu E, Nyarko KM, Mahama JY, Sackey SO, *et al.*** Evaluation of the enhanced meningitis surveillance system, Yendi municipality, northern Ghana, 2010-2015. BMC Infect Dis 2017; 17:(1): 306.
17. **Clemence MEA, Maiden MCJ, Harrison OB.** Characterization of capsule genes in non-pathogenic Neisseria species. Microb Genom 2018;4(9):e000208.
18. **Calder A, Menkiti CJ, Çağdaş A, Lisboa Santos J, Streich R, *et al.*** Virulence genes and previously unexplored gene clusters in four commensal *Neisseria* spp. isolated from the human throat expand the neisserial gene repertoire. Microb Genom 2020;6(9):mgen000423.
19. **Chen M, Zhang C, Zhang X, Chen M.** Meningococcal Quinolone Resistance Originated from Several Commensal *Neisseria* Species. Antimicrob Agents Chemother 2020;64(2):e01494-19.
20. **Khan FY, Abu-Khattab M, Almaslamani EA, Hassan AA, Mohamed SF, Elbuzdi AA, *et al.*** Acute bacterial meningitis in Qatar: a hospital-based study from 2009 to 2013. BioMed research international 2017. 2017:2975610.
21. **Parlet CP, Brown MM, Horswill AR.** Commensal staphylococci influence Staphylococcus aureus skin colonization

and disease. Trends in microbiology 2019; 27:(6): 497-507.

22. **Mazamay S, Guégan JF, Diallo N, Bompangue D, Bokabo E, Muyembe JJ, *et al.*** An overview of bacterial meningitis epidemics in Africa from 1928 to 2018 with a focus on epidemics "outside-the-belt". BMC Infect Dis 2021;21(1):1027.
23. **Hamed MM, Mir FA, Elmagboul EBI, Al-Khal A, Maslamani MARSA, Deshmukh AS, *et al.*** Molecular characteristics of Neisseria meningitidis in Qatar. Sci Rep 2021;11(1):4812.
24. **Amissah NA, van Dam L, Ablordey A, Ampomah OW, Prah I, Tetteh CS, *et al.*** Epidemiology of Staphylococcus aureus in a burn unit of a tertiary care center in Ghana. PLoS One. 2017;12(7):e0181072.

Amewu EKA, Adu-Asiamah CK, Baba-Adam R, Afful A, Boahen KG, Kwarteng A. Oropharyngeal carriage of potential meningitis-causing bacteria in a Ghanaian prison. Microbes Infect Dis 2023; 4(2): 487-496.