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A Study of the Performance of Health Districts in the Diagnosis of Acute Bacterial Meningitis within the Framework of Epidemiological Surveillance of Meningitis in Burkina Faso from 2015 to 2022

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ABSTRACT

Introduction: *In health districts in Burkina Faso, microscopic diagnosis of bacterial meningitis is essential for surveillance and rapid case management. This study aimed to study the concordance of microscopy results with those of PCR in health district laboratories during the diagnosis of bacterial meningitis.*

Methods: *This was a retrospective study with a descriptive and analytical aim which involved 70 health districts attached to the 4 national level laboratories and the national meningitis reference laboratory (at the Charles De Gaulle Pediatric University Hospital) from 1 January, 2015 to 31 December, 2022. The data were collected based on data from the epidemiological surveillance of meningitis 2010 - 2022. The data collected were entered into Microsoft Excel version 2016 software and analyzed using Epi info version 7 software.*

Results: *The study included 70 health districts with 4,078 suspected cases of meningitis. Males accounted for 56% of patients, and 34.39% of patients were between 29 days and 30 months of age. This study showed that 5 health districts performed very well, with an overall discordance of 0% and 10%, 32 health districts performed well, with an overall discordance of 10.1% and 25%, 26 health districts performed moderately well, with an overall discordance of 25.1% and 40%, 2 districts performed fairly well, with an overall discordance of 40.1% and 50%, and 5 districts performed poorly, with an overall discordance of 50.1% and 100%.*

Conclusion: *The health districts are generally performing well, but capacity building among staff in some districts is necessary.*

Keywords
Performance, Health districts, Bacterial meningitis, Epidemiological surveillance.

Introduction
Meningitis is an inflammation of the meninges, the membranes surrounding the brain and spinal cord [1]. It can be caused by various pathogens, including bacteria, viruses, fungi, or parasites. The bacterial form of the disease is of particular concern due to its severity and high lethality. Transmission of bacterial agents, particularly *Neisseria meningitides, Streptococcus pneumoniae, and Haemophilus influenzae serotype b,* occurs primarily through

respiratory droplets or pharyngeal secretions emitted by infected individuals or healthy carriers [1].

Despite considerable progress in prevention and treatment, bacterial meningitis remains a major public health problem, especially in the "African meningitis belt," a region stretching from Senegal in the west to Ethiopia in the east. The World Health Organization (WHO) estimates that more than 1.2 million cases of meningitis occur each year worldwide, with a case fatality rate of up to 70% in the absence of treatment [2]. In 2023, 24 countries in this belt reported 28,421 suspected cases, including 1,238 deaths, representing a case fatality rate of 4.4%. Burkina Faso was among the most affected countries with more than 1,609 clinical cases [2].

To address this challenge, Burkina Faso introduced the meningococcal serogroup A conjugate vaccine (MenAfriVac®) in 2010 and adopted, in accordance with WHO recommendations, a case-by-case surveillance strategy. This strategy requires biological confirmation of each suspected case of meningitis, mainly from laboratory analysis of cerebrospinal fluid (CSF) [3]. Thus, laboratories become essential links in the epidemiological surveillance system and in the rapid management of patients. As part of the fight against acute bacterial meningitis, the country has established a network of reference laboratories, equipped to carry out confirmatory diagnoses using highly sensitive and specific methods, such as polymerase chain reaction (PCR) and CSF culture [4].

However, in peripheral health facilities, particularly district laboratories, initial diagnosis is based mainly on more accessible and rapid methods, namely direct microscopic examination in the wet state and Gram staining and immunological tests [5]. These analyses play a central role in immediate diagnostic orientation and in the early initiation of probabilistic antibiotic therapy, which is essential to reduce morbidity and mortality linked to these infections [6]. However, the reliability of microscopy in these peripheral settings is variable and is rarely compared with the results obtained by reference methods. It therefore becomes essential to measure the diagnostic performance of microscopy, in terms of sensitivity, specificity and concordance with PCR, in order to determine its relevance as a monitoring and clinical guidance tool. This study aims to investigate the concordance of microscopy results with those of PCR in health district laboratories during the diagnosis of bacterial meningitis.

Materials and Methods

Study Sites

Reference Meningitis Testing Laboratories

The study was conducted at the National Reference Laboratory (NRL) for meningitis at the Charles De Gaulle Pediatric University Hospital (CDG- PUH). This university hospital represents the third level in the technical organization of the Burkina Faso healthcare system. It provides specialized healthcare services, as well as a laboratory with high-performance equipment and skilled personnel. In addition to routine bacteriological diagnosis of CSF, this laboratory has a state-of-the-art technical platform (PCR) for confirming cases of bacterial meningitis using molecular biology.

According to the organization set up within the framework of meningitis surveillance, in addition to the NRL, the Laboratory of the National Agency for Health Safety, Environment, Food, Work and Health Products (ANSSEAT), the laboratories of the University Hospitals Yalgado Ouédraogo (UH-YO) and Souro Sanou (UH-SS), and the Muraz Centre are considered as National Level Laboratories (NLL). They are also responsible for confirming cases of meningitis by analyzing CSF by PCR and culture, the preliminary part of which (direct examination was done by peripheral laboratories).

Peripheral Laboratories

These are the laboratories of district hospitals. A total of 70 health districts are spread across Burkina Faso. The Health and Social Promotion Centers (HSPC), Medical Centers (MC), and Medical Centers with Surgical Units (MCSU) form the district health facilities. They represent the first level in the technical organization of the health system in Burkina Faso. At the district level, the direct referral health center for the HSPC and MC is generally the MCSU. The latter has a laboratory where the first part of the bacteriological analysis of CSF (microscopy) and the search for soluble antigens are performed for the management of suspected cases of meningitis. After these preliminary examinations, the samples are sent to the NLL or NRL for confirmation as part of bacterial meningitis surveillance.

Study Type and Period

This was a retrospective, descriptive and analytical study that included CSF samples from January 1, 2015, to December 31, 2022.

Study Population

This study included all suspected cases of meningitis whose CSF samples were collected in the health districts as part of meningitis epidemiological surveillance. These samples were analyzed by PCR in the NLLs during the study period.
The CSF samples included in the study were those collected and analyzed by microscopy in the health districts and by PCR in the NLLs and at the NRL meningitis as part of meningitis epidemiological surveillance during the study period.

This was a comprehensive sampling based on the systematic recruitment of all samples collected and analyzed by microscopy and PCR as part of epidemiological surveillance during the study period.

Health District Performance Assessment Criteria

The following results were considered discordant:
False-positive results: when the Gram stain result from microscopic examination of CSF at the district laboratory is positive while the PCR result performed on the same sample at the NLL or NRL is negative.

False-negative results: when the Gram stain result from microscopic examination of CSF at the district laboratory is negative while the PCR result performed on the same sample at the NNL or NRL is positive.

Discordant results for pathogen identification: when the Gram stain results do not match the identification made by PCR.

Distribution of Discrepancies by Segment

The frequencies of each discrepancy (false positive, false negative, discordant germs) were determined for each district and then expressed as a percentage. The discrepancy ranges were assessed as follows [7]: 0% - 5%: very good, 5.1% - 10%: very good, 10.1% - 15%: good, 15.1% -20%: good, 20.1%-25%: good, 25.1%-30%: average performance, 30.1%-35%: average performance, 35.1%-40%: average performance, 40.1%-45%: fair performance, 45.1%-50%: fair performance, 50.1%-55%: insufficient performance, 55.1%-60%: insufficient performance, 60.1%-65%: insufficient performance, 65.1%-70%: insufficient performance, 70.1%-75%: insufficient performance, 75.1%-80%: performance insufficient, 80.1%-85%: insufficient performance, 85.1%-90%: insufficient performance, 90.1%-95%: insufficient performance, 95.1%-100%: insufficient performance.

The districts were then grouped into these discordance bands based on their discordance results.

To assess the discordance bands, the overall discordance for each district was determined by summing its discordance results (percentage of false positives + percentage of false negatives + percentage of discordant germs). Overall discordance bands were then created with ratings as follows [7]: 0%-10%: high performance, 10.1%-25%: high performance, 25.1%-40%: average performance, 40.1%-50%: fair performance, 50.1%-100%: poor performance. The districts were then grouped into these overall discordance bands based on their overall discordance results.

Data Analysis and Processing

The data sources were the 2010–2022 meningitis epidemiological surveillance database. The data were entered using Microsoft Excel 2016. In addition to the database data, five columns (discordant organisms, true positive, false positive, true negative, false negative) were created for comments. Comments consisted of answering yes or no in these five columns for each sample analyzed by comparing the Gram stain result to the PCR result, with the PCR result being the reference.

Two (2) columns were created to record the month the sample was received and the age of each patient using existing data from the 2010–2022 epidemiological surveillance database (date of consultation, date of birth). The entered and commented data were analyzed using Epi info software version 7.2.5.0. This software made it possible to determine the frequencies of the following variables: sex, age, month of sample receipt, PCR results, Gram staining, discordant germs, true positive, false positive, true negative and false negative. The proportions (n) of: false positive, false negative, discordant germs were determined by district.

Ethical and Professional Conduct

This study was subject to authorization from CHUP-CDG management. Data collection was carried out with strict respect for patient anonymity, and the identity of the health districts was kept confidential.

Results

Description of the Study Population

A total of 4,078 suspected cases of meningitis were identified, including 2,267 males (56%), representing a sex ratio of 1.29.

According to the age group of the entire study population, 27, or 0.66%, were less than 29 days old, 1,402 suspected cases, or 34.39%, were aged between 29 days and 30 months. Finally, 642 suspected cases, or 15.74%, were in people aged 16 years and older.

As shown in Figure 1 below, the number of suspected meningitis cases varied by month and year. They were particularly high in February and March. The lowest number of suspected meningitis cases occurred between June and December. In terms of year, the peaks were observed in 2015, 2016 and 2018.

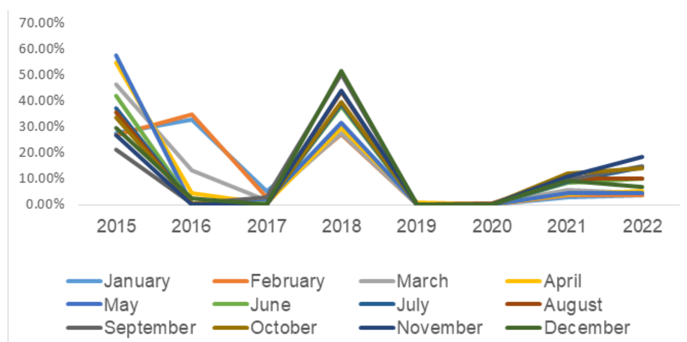

Figure 1: Distribution of suspicious cases according to month and year.

The health districts of Po, Bogodogo, and Zorgho had the highest number of LCS samples, with 256,210 and 198, respectively.

The health districts of Dori, Baskuy, Barsalgho, Mangodara, Léna, Thiou, Karangasso, and Tougouri had the lowest number of LCS samples, with 1, 1, 3, 3, 4, 4, 4, and 10, respectively.

Probable Cases Based on CSF Microscopy in Health Districts

Microscopic analyses in health districts revealed the morphology of a total of 890 organisms in the 4,078 samples analyzed, representing a positivity rate of 2.18%. These organisms were as follows: 596 (66.94%) Gram-positive diplococci (GPD), 203 (22.83%) Gram-negative diplococci (GND), 54 (6.11%) Gram-negative bacilli (GNB), 30 (3.34%) Gram-positive bacilli (GPB), and 7 (0.78%) other organisms.

PCR-confirmed Cases

A total of 1,176 bacteria were detected by PCR in the 4,078 samples analyzed, representing a positivity rate of 2.88%. They are composed of 65.99% *Streptococcus pneumoniae* (DGP), 27.56% *Neisseria meningitides* (DGN), 6.37% *Haemophilus influenzae* (BGN) and 0.08% *Streptococcus agalactiae* (CGP).

Health District Performance

Overall Health District Performance

Microscopic analyses of the health districts yielded 943 discrepant results. Of the 4,078 samples analyzed, there were 13.54% false negatives, as shown in Table 1 below.

Table 1: Overall performance of health districts.

Variables	Number	Frequency (%)
False negative	552	13.54
False positive	266	6.52
Discordant germs	125	3.06
Sensitivity	0.42	42.43
Specificity	0.91	90.83
PPV	0.65	65.23
NPV	0.83	82.68

PPV: Positive predictive value; NPV: Negative predictive value.

Performance by Health District

Four (4) districts had an overall discordance between 0 and 5% with a total sample size of 225. One district had an overall discordance between 5.1 and 10% with 70 samples.

Five (5) districts had the highest overall discordance, with two having a total sample size of 62 and the other three having 47.4 and 1 sample size, respectively (see Table 2).

Table 2: Distribution of Overall Discordance Ranges.

Discrepancy slices (%)	Number of district	*Total sampling received*
0-5	4	225
5.1-10	1	70
10.1-15	5	264
15.1-20	13	902
20.1-25	14	1183
25.1-30	14	746
30.1-35	6	289
35.1-40	6	251
40.1-45	1	30
45.1-50	1	4
50.1-55	2	62
60.1-65	1	47
70.1-75	1	4
95.1-100	1	1

Of the 70 health districts, in the 0 to 5% range, 35 districts had false positives, 56 had discordant germs. The dispersion of health districts was more remarkable at the level of false negatives with only 13 districts in this range of 0 to 5% (See Table 3).

Appreciation of the performance of the health districts

As is shown in table 4, 5 health districts performed very well, with a global discordance comprised between 0 and 10%.

Table 3: Distribution of districts according to the slices and types of discrepancies.

False positives (N)	False negatives (N)	Discrepant germs (N)	Discrepant slice (%)
35	13	56	0-5
19	14	11	5.01-10
5	11	3	10.01-15
6	18	0	15.01-20
1	3	0	20.01-25
0	2	0	25.01-30
2	4	0	30.01-35
0	2	0	35.01-40
1	2	0	45.01-50
0	1	0	70.01-75
1	0	0	95.01-100

Table 4: Appreciation of the performance of the districts.

Appreciation	*Number of health district*	*Slice discrepancy (%)*
Very performant	5	0-10
Performant	32	10.1-25
Average performance	26	25.1-40
Fair performance	2	40.1-50
Insufficient performance	5	50.1-100

Discussion

The study showed a male predominance with a sex ratio of 1.29. A study on meningitis surveillance in Benin reported the same sex ratio of 1.29 [8]. Other studies have also shown a predominance of male patients, such as those by Ouhssain et al. in Morocco [9] and Ouangraoua et al. in Burkina Faso [10]. The majority of patients were young (under 16 years old) with a predominance of infants (34.39%). An evaluation of bacterial meningitis surveillance in Togo reported a predominance of cases among young people (under 16 years old), especially children aged 0 to 5 years (37.8%) [11].

Similar results were observed in the study conducted by Diarra et al. in Mali, comparing diagnostic methods for bacterial meningitis [5]. This vulnerability in young people is mainly explained by the immaturity of their immune system. Meningitis occurs throughout the year with peaks during the months of February (20.16%) and March (16.13%). The Ouangraoua team in their study on bacterial meningitis in western Burkina Faso reported the endemic nature of the disease with peaks in February, March and April [12]. The endemic nature of this disease was also reported in Mali with peaks in February (16.6%), March (34.6%) and April (20.7%) [5]. These peaks are explained by the harmattan (dry and hot wind) and the heat during these months which irritate and dry out the mucous membranes of the human nasopharynx, thus promoting infections.

The results of microscopic analyses of the health districts gave a total of 890 germs on the 4078 samples analyzed including 66.94% of DGP, 22.83% of DGN, 6.11% of BGN, 3.34% of BGP and 0.78% of other germs, i.e. a positivity rate of 2.18%. The PCR detected 1176 bacteria on the same samples, i.e. a positivity rate of 2.88%.

Among the species identified by PCR, Streptococcus pneumoniae represented 65.99%, followed by Neisseria meningitides (27.56%), Haemophilus influenzae (6.37%) and Streptococcus agalactiae (0.08%). These results show that the positivity rate by microscopy is close to that of PCR, which is the reference method. This is a good performance which shows that the diagnosis of meningitis in rural areas based on microscopy is effective.

Compared with the PCR results, the microscopic analyses of the 70 health districts gave an overall discordance of 943, or 23.12% of the 4078 samples analyzed. This overall discordance was composed of 13.54% false negatives (n=552), 6.52% false positives (n=266) and 3.06% discordant germs (n=125). In other words, the results of the microscopic analyses gave 42.43% true positives, 46.94% false negatives and 10.63% discordant germs of the 1176 germs detected by PCR. A study evaluating diagnostic methods for bacterial meningitis in the Central African Republic showed that microscopy could detect 42% of the agents identified by PCR [13], a result comparable to that observed in the present study. In contrast, a study conducted in Brazil reported a significantly higher sensitivity, with a microscopy detection rate reaching 97.5% [14], which is significantly higher. than the result of this study.

This high variability in microscopy performance is explained by the fact that it is linked to several factors such as the technician's expertise, the condition of the binocular microscope, the quality of the fixation and staining reagents, the bacterial inoculum, the quality of the sample and the sample delivery time. Although the overall discordance, estimated at 23.12%, may seem relatively low. The frequency of false positives and false negatives remains high, unlike the discordances observed in the identification of pathogens. This situation highlights the need to strengthen the technical skills of laboratory staff at the district level. Furthermore, the examination of discordances by district shows heterogeneity in performance, with some districts showing good results while others have clearly insufficient performance.

This study showed that 5 health districts performed very well with an overall discordance of between 0 and 10%, 32 health districts performed well with an overall discordance of between 10.1 and 25%, 26 health districts performed moderately well with an overall discordance of between 25.1 and 40%, 2 districts performed fairly well with an overall discordance of between 40.1 and 50% and 5 districts performed poorly with an overall discordance of between 50.1 and 100%. Of the 5 health districts that performed very well, 4 districts had an overall discordance of between 0 and 5%, i.e. at least 95% good results of microscopic analyses with a total sample of 225. Only one district had an overall discordance of between 5.1 and 10%, i.e. between 80 and 94.9% good results of microscopic analyses of the 70 samples. Of the 32 districts that performed well, 5 districts had an overall discordance of between 10.1 and 15%, i.e. between 85 and 89.9% good results with a total sample of 264. Thirteen (13) districts had an overall discordance of between 15.1 and 20%, i.e. between 84.9 and 80% good results with a total sample of 902. Fourteen (14) districts had an overall discordance of between 20.1 and 25% or between 75 and 79.9% of good results with a total sample of 1183. Among the 26 average performing districts, 14 districts had an overall discordance of between 25.1 and 30% or between 70 and 74.9% of good results with a total sample of 746. Six (6) districts had an overall discordance of between 30.1 and 35% or between 65 and 69.9% of good results with a total sample of 289. Six (6) other districts had an overall discordance of between 35.1 and 40% or between 60 and 64.9% of good results with a total sample of 251. Of the 2 fairly performing districts, one had an overall discordance of between 40.1 and 45% or between 50 and 69.9% of good results with a total sample of 289. 55 and 59.9% good results with 30 samples and the other had an overall discordance of between 45.1 and 50% or between 50 and 54.9% good results with 4 samples. Of the 5 underperforming districts, two (2) had an overall discordance of between 50.1 and 55% or between 45 and 49.9% good results with a total sample of 62. One district had a discordance of between 60.1 and 65% or between 35 and 39.9% good results with 47 samples.

Another district had an overall discordance of between 70.1 and 75%, or between 25 and 29.9% of good results with 4 samples. The last district had an overall discordance of between 95.1 and 100 with 1 sample. The performance of microscopy varied between 47 and 87% depending on the studies [15]. This great variability in the performance of health districts could be explained by the size of the samples analyzed. Indeed, among the 70 districts, 19 each had a number of samples less than 20, of which seven (07) had less than 10 samples. Overall, the health districts of Burkina Faso are performing well with 76.88% of good results from microscopic analyses.

Conclusion

The study demonstrated that Burkina Faso's health districts are generally efficient in microscopic examination of CSF as part of epidemiological surveillance of bacterial meningitis. This performance, which varies greatly from one district to another and is dependent on several parameters such as the time and conditions of transport of CSF to the laboratory, the quality of supplies, and the technical expertise of staff, requires capacity building through regular training supervision of laboratory staff.

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