Infect Dis Ther (2023) 12:2337–2351
https://doi.org/10.1007/s40121-023-00869-z

REVIEW

Range of Clinical Manifestations Caused by Invasive Meningococcal Disease Due to Serogroup W: A Systematic Review

Isabelle Bertrand-Gerentes · Laurent Fanchon · Florence Coste · Richard E. Glover · Tamazoust Guiddir · Muhamed-Kheir Taha

Received: June 6, 2023 / Accepted: September 1, 2023 / Published online: September 26, 2023

ABSTRACT

Introduction: Invasive meningococcal disease (IMD) due to serogroup W meningococci (MenW) is consistently reported with atypical clinical manifestations, including gastrointestinal symptoms, bacteremic pneumonia, and septic arthritis. We undertook a systematic review of the literature for a comprehensive assessment of the clinical presentation of IMD caused by MenW.

Methods: PubMed and Embase databases were searched from inception to June 2022 using a combination of MeSH terms and free text for articles that reported symptoms and signs of MenW IMD, and associated manifestations.

Results: The most commonly reported symptoms identified included: fever (range 36–100% of cases), nausea and/or vomiting (range 38–47%), vomiting (range 14–68%), cough (range 7–57%), sore throat (range 13–34%), headache (range 7–50%), diarrhea (range 8–47%), altered consciousness/mental status (range 7–38%), stiff neck (range 7–54%), and nausea (range 7–20%). Sepsis (range 15–83% of cases) was the most commonly reported manifestation followed by meningitis (range 5–72%), sepsis and meningitis (range 6–74%), bacteremic pneumonia (range 4–24%), arthritis (range 1–15%), and other manifestations (e.g., pharyngitis/epiglottitis/supraglottitis/tonsillitis/conjunctivitis; range 1–24%). The case fatality

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40121-023-00869-z.

I. Bertrand-Gerentes · L. Fanchon (✉) · F. Coste
Global Medical Affairs, Sanofi, 14 Espace Henry Vallée, 69007 Lyon, France
e-mail: Laurent.Fanchon@sanofi.com

I. Bertrand-Gerentes
e-mail: Isabelle.Bertrand-Gerentes@sanofi.com

F. Coste
e-mail: Florence.Coste@sanofi.com

R. E. Glover
Springer Healthcare Ltd, Chowley Oak Lane, Tattenhall CH3 9GA, Chester, UK
e-mail: Richard.glover@springer.com

T. Guiddir
Department of Pediatrics, Paris-Saclay University, APHP, Bicêtre Hospital, 78 Avenue du Général Leclerc, 94270 Le Kremlin-Bicêtre, France
e-mail: tamazoust.guiddir@aphp.fr

M.-K. Taha
Institut Pasteur, Université Paris Cité, Invasive Bacterial Infections, National Reference Centre for Meningococci and Haemophilus Influenzae, 25-28 Rue du Dr Roux, 75015 Paris, France
e-mail: muhamed-kheir.taha@pasteur.fr

rates ranged from 8–40%, and among the survivors 4–14% had long-term sequelae.
Conclusions: Clinicians need to be aware of the nonspecific symptoms and signs of IMD, as well as of the atypical manifestations in regions where MenW is known to circulate to ensure timely diagnoses and treatment.

Keywords: Invasive meningococcal disease; Serogroup W; Symptoms

Key Summary Points

Meningococcal serogroup W (MenW) has increasingly become a cause of invasive meningococcal disease (IMD).

However, a high proportion of cases of IMD due to MenW may have atypical clinical manifestations.

We undertook a systematic literature review to comprehensively assess the reported clinical presentations of IMD due to MenW.

Although most cases of MenW disease have typical IMD symptoms, atypical presentations (pneumonia, arthritis, and upper respiratory/ophthalmological presentations) were reported in a sizeable proportion of cases.

To aid timely diagnosis and treatment, clinicians should be aware of the full spectrum of MenW IMD presentations.

INTRODUCTION

Neisseria meningitidis (*N. meningitidis*) is a commensal obligate human pathogen and a frequent colonizer of the nasopharyngeal mucosa, with 5–10% asymptomatic carriage rates at any given time [1, 2]. Adolescents are considered the principal reservoir and the most likely source of transmission [3, 4]. *N. meningitidis* can be responsible for invasive meningococcal disease (IMD), with an overall notification rate in Europe of 0.6 per 100,000 population between 2015 and 2017 [5]. The processes leading to IMD are not fully understood, but usually start on acquisition of invasive isolates [6], leading to serious morbidity associated with 10–15% fatality rates even with appropriate treatment [7]. Among those who survive IMD, 10–20% will have long-term disability [8].

To date, there have been 12 *N. meningitidis* serogroups identified, based on the immunologic reactivity of their polysaccharide capsule [9, 10]. However, almost all IMD cases are caused by serogroups A, B, C, W, X, and Y [1, 7]. The distribution and frequency of the six epidemiologically relevant serogroups varies by region, over time, and host age-group [11]. Most regions have experienced a decline in the incidence of IMD in recent years due mainly to the success of vaccination programs [11–13]. A further decrease also occurred upon the implementation of containment measures to control the coronavirus disease 2019 (COVID-19) pandemic [14].

Serogroup W has a relatively recent history in the epidemiology of *N. meningitidis*. After its first description in the late 1960s [15], reports of IMD caused by serogroup W (MenW) remained sporadic. Its role, on an international scale, was first described in 2000 with the epidemic among pilgrims to Mecca and their contacts [16]. This "Hajj" epidemic included cases of MenW of clonal complex 11 (cc11) [17]. As pilgrims returned to their countries of origin, the "Hajj" strains (later named the "Anglo-French Hajj" lineage [18]) spread rapidly from Saudi Arabia to the sub-Saharan African meningitis belt, South Africa, and Europe during 2000–2003, but declined thereafter [19, 20], and reappeared again in sub-Saharan Africa after 2010 [21].

In parallel, since 2003, an increase in IMD caused by MenW cc11 has been observed in South America, particularly in Brazil, Argentina, and Chile [22–24]. Since 2009/2010, there has also been an increase in MenW cc11 cases in Europe, Australia, Canada, North America, Asia, as well as a persistence of this strain in South America. The incidence of MenW IMD increased in European countries between 2013 and 2017: the Netherlands, Germany, Spain, Sweden, Switzerland, and France [25]. Thus, recently, concomitant multifocal expansion of

MenW has been observed in several areas worldwide (America, Europe, Oceania, Asia, Africa). The relationship between this recent wave of expansion of IMD MenW cc11 and the "Anglo-French Hajj" lineage that was described in the 2000s was resolved using whole genome sequencing that allowed the description of two independent lineages: the "Anglo-French Hajj" lineage and the "South American/UK" lineage [18]. The Anglo-French Hajj lineage emerged in the 2000s with the Hajj epidemic. The "South American/UK" lineage emerged in South America and then spread rapidly to Europe and beyond [26]. This latter lineage quickly diversified and generated the "Original UK" sub-lineage in 2009 and the "UK 2013" sub-lineage which spread rapidly to other European countries from 2013 [18].

Although sepsis and/or meningitis are the most common manifestations of IMD, a high proportion of invasive MenW cases have been reported to include atypical (non-meningeal) clinical presentations, such as bacteremic pneumonia, septic arthritis, and myocarditis [27]. A recent systematic review found that atypical MenW IMD presentation included acute gastrointestinal (GI) symptoms, septic arthritis and bacteremic pneumonia or severe upper respiratory tract infection (mainly epiglottitis) as prevalent symptoms [28]. That review, however, focused the literature search on these specific symptoms and was limited to the PubMed database and atypical presentation. In this article, we widened the literature search across two databases using a wider range of symptoms, signs and manifestations for a more comprehensive assessment of serogroup W IMD clinical presentation.

METHODS

Search Strategy

A systematic search of PubMed and Embase was undertaken via the ProQuest interface on 17 June 2022 without date restrictions using the following combination of search terms: (((neisseria OR bacterial meningitis OR meningococcal infections[MeSH Terms]) OR (meningococc*[Text Word] OR Neisseria[Text Word] OR meningitis[Text Word])) AND ((-meningococcus, serogroup W 135[MeSH Terms]) OR (Serogroup W[Text Word] OR group W[Text Word] OR MenW[Text Word]))) AND (sepsis or septicemia or septic shock or meningococcemia or arthritis or urethritis or pericarditis or GI or gastrointestinal or gastroenteritis or gastro-enteritis or septic arthritis or respiratory or epiglottitis or supraepiglottitis or abdominal or pain or confusion or agitation or cold symptom or fever or chill or pharyngitis or peritonitis or endocarditis or myocarditis or myopericarditis or (extra-meningeal and (articular or pericardial or ocular)) or painful urin* or arthralgia or myalgia or asthenia or abducens palsy or cerebellitis or cerebellar infarction or nausea or diarrhoea or diarrhea or vomiting or necrotizing fasciitis or petechiae or conjunctivitis or rash or purpura fulminans or acute renal failure or kidney failure or disseminated intravascular coagulation or "upper respiratory tract symptoms" or headache or neck stiffness).

Eligibility Criteria

We sought original articles published in English (or at least had an English abstract) describing the clinical manifestation of laboratory-confirmed (as defined by the studies: culture, PCR, whole genome sequencing, latex agglutination) invasive *N. meningitidis* serogroup W (MenW) disease. We excluded articles that presented no original clinical data or were immunogenicity, carriage, surveillance, risk factor, genomic, biochemical characterization, or survey studies without information about clinical presentation. Clinical trials and vaccine studies were also excluded. The reference lists of review papers identified in the initial electronic search were checked for other potentially relevant reports.

Initially, titles and abstracts of all citations identified were assessed as a first step to exclude those that did not meet the inclusion criteria. Articles where there was any doubt as to their relevance to the current review and those that met the predefined selection criteria were obtained and fully analyzed in a second step.

Those with appropriate data were retained, with no restriction on patient population, geographical location, study design, or sample size. Information of the clinical presentation of laboratory-confirmed invasive MenW disease were entered into a standardized data table; the data summarized included region, patients' age and sex, study design, MenW confirmation methods, number of patients and symptoms reported before treatment initiation, and clinical manifestations (including outcomes).

For the purpose of the current review, clinical manifestations were categorized as meningitis, sepsis, sepsis and meningitis, pneumonia (with meningococcemia and with/without sepsis or meningitis), arthritis (with/without sepsis or meningitis), and other (with/without sepsis or meningitis). The definitions used for the manifestations differed between studies, and, as such, we utilized the definitions used within the studies identified without further modification. In general, meningitis was based on symptoms consistent with disease along with a positive cerebrospinal fluid culture/PCR, with or without positive blood culture/PCR. Similarly, sepsis was based on symptoms and a positive blood culture/PCR without a positive cerebrospinal fluid culture/PCR, although some studies did report this with meningitis [29]. Bacteremic pneumonia was based on symptoms in combination with positive blood culture/PCR. Other noninvasive diseases such as conjunctivitis, urethritis, epiglottitis, supraglottitis, or tonsillitis were only included if these were in conjunction with a positive blood culture/PCR. Arthritis was based on joint symptoms along with a positive joint fluid culture/PCR. The latter manifestations were categorized irrespective of sepsis or meningitis. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

Statistical Analyses

There were no additional statistical analyses undertaken beyond those reported in the original studies; the data were synthesized to provide a narrative summary as the heterogeneity between studies precluded any meaningful statistical analyses.

RESULTS

Study Selection

Sixty-seven publications were selected for inclusion in the systematic review (Fig. 1), including four found from other sources [30–33]. Publication dates ranged from 1980 through to 2021 and included data from Africa (n = 3), Australasia (n = 7), East Asia (n = 9), Europe (n = 39), Middle East (n = 2), North America (n = 4), South America (n = 2), and Europe/Asia (n = 1). The study designs included (Supplementary Tables S1 and S2): single case (n = 32) [33–64], cases series (up to 10 cases) (n = 11) [65–75], hospital-based (including case series with > 10 cases) (n = 7) [76–82], or surveillance studies (n = 17) [29–32, 83–95]. Of the hospital-based or surveillance studies, six were prospective [77, 79, 80, 86, 87] or included a prospective component [83].

Age Affected Over Time

We assessed whether the age of MenW IMD cases reported had changed over time, by comparing ages of the cases reported in "old" and more recent publications. For the case studies (i.e., single case studies and studies that reported data for ≤ 10 cases), a scatterplot of the case age and year of publication shows the earliest cases reported from the 1980s were mainly adults, then from the 1990s through to 2010 cases were predominantly children and adolescents/young adults, and subsequently since 2010 cases were reported across all age groups (Fig. 2). We focused on single/small case studies because the ages of the cases are nearly always reported, the disease would have occurred at narrowly define time, and each case in the scatter plot would be of equal weight/relevance. Larger studies usually report data over a wider time period with the ages of the cases usually

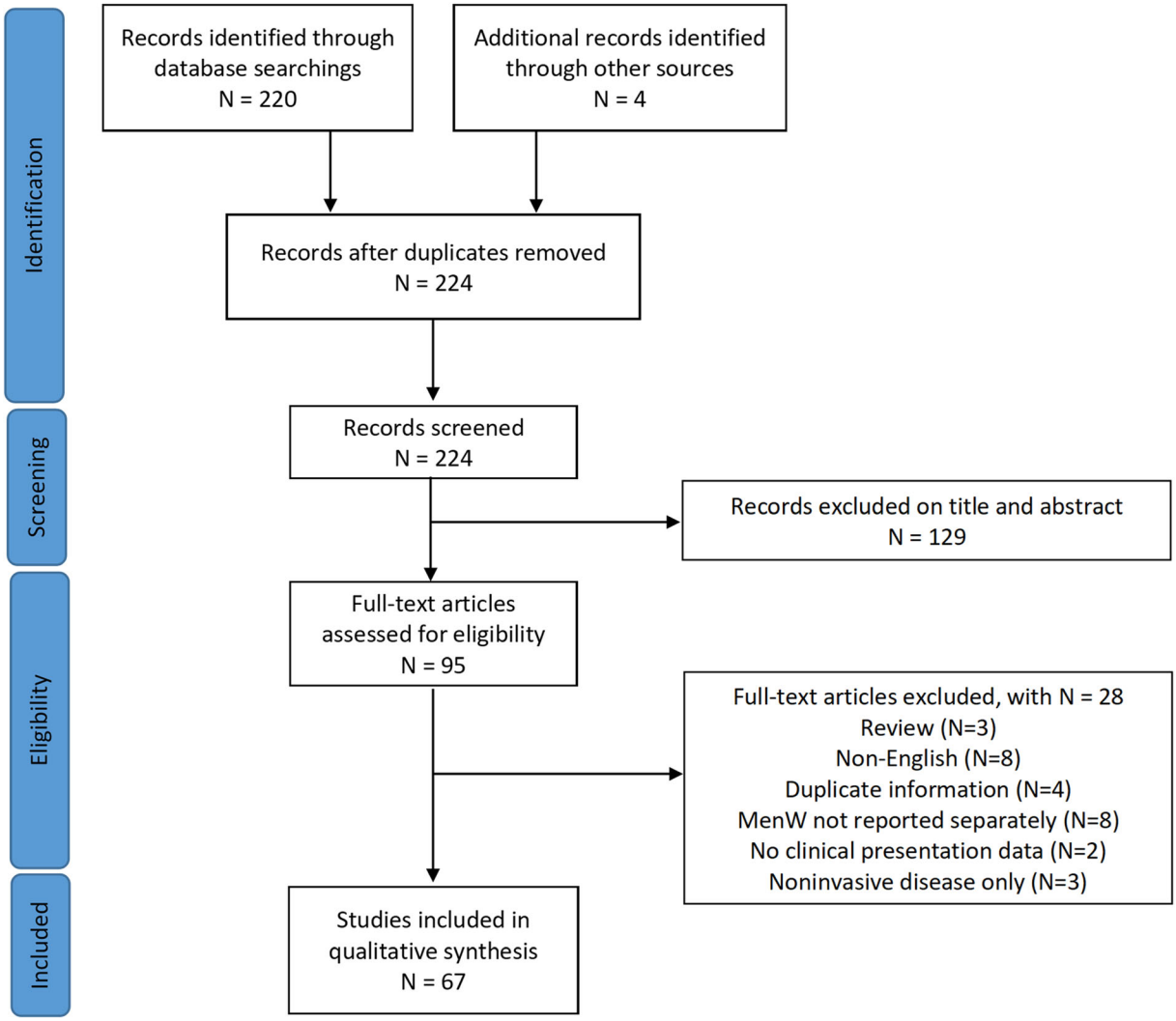

Fig. 1 PRISMA flowchart for the selection of articles included

aggregated, making identifying trends in the age of cases reported over time difficult.

Symptoms

The top ten common symptoms and signs reported among the studies that report symptomology for up to ten cases, encompassing 74 (28 female and 36 male; 10 with sex information missing) cases with confirmed MenW IMD, are summarized in Table 1. These included: fever, pain, vomiting, rash/spots, headache, diarrhea, altered consciousness/mental status, cough, stiff neck, low blood pressure, and tachycardia.

Among the studies that report symptomology for > 10 cases, encompassing 3208 cases with confirmed MenW IMD, the top ten common symptoms and signs reported included (Table 2): fever, nausea and/or vomiting, vomiting, cough, sore throat, headache, diarrhea, altered consciousness/mental status, stiff neck, and nausea.

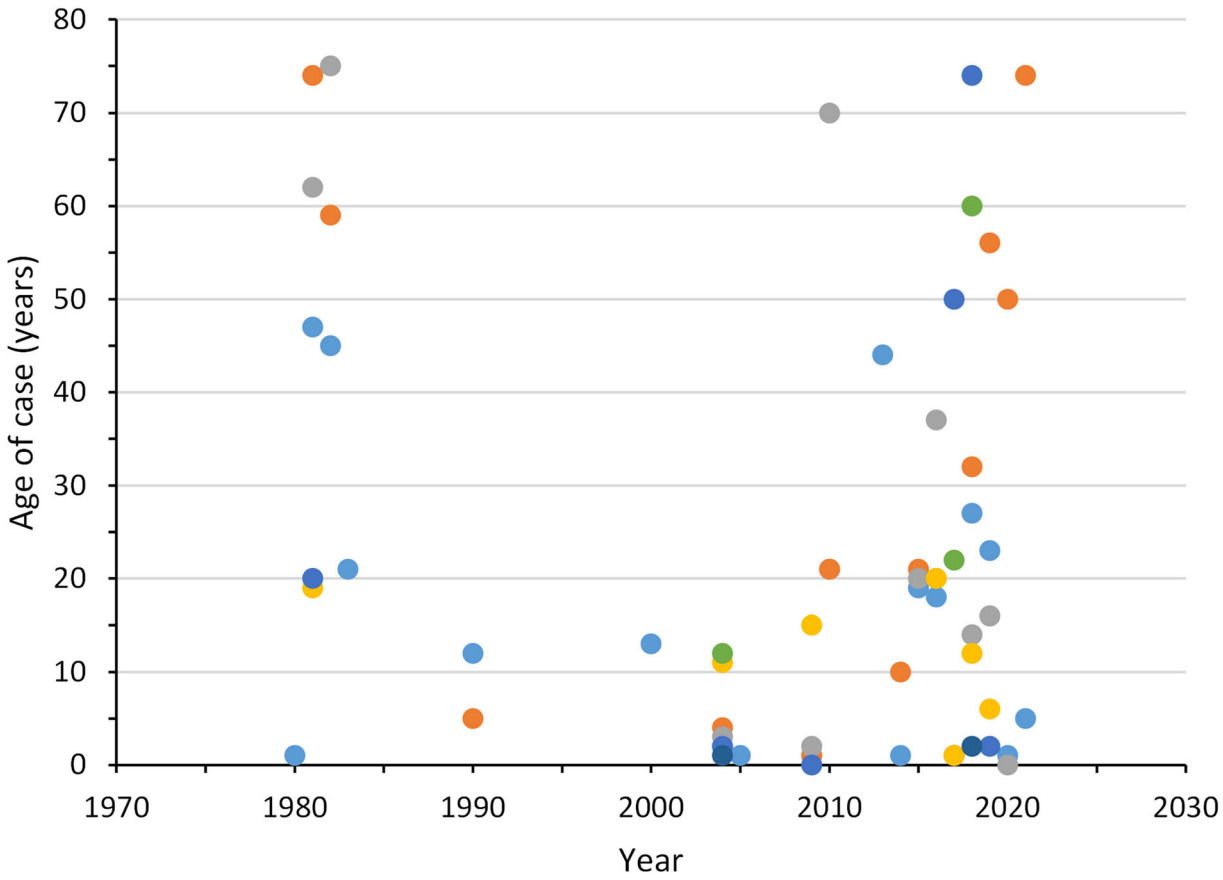

Fig. 2 Age affected over time: scatterplot of the case age and year of publication (single case studies or studies that reported data for ≤ 10 cases). Each dot represents an individual case

Clinical Manifestations

The main clinical manifestations among the studies that reported data for individual cases (up to ten cases) are summarized in Table 3. These included: sepsis, meningitis, sepsis and meningitis, arthritis, bacteremic pneumonia, and other. Of the 74 cases reported, 11 died.

The clinical manifestations among studies that reported data for > 10 cases are summarized in Table 4. These included: sepsis, meningitis, sepsis and meningitis, bacteremic pneumonia, arthritis, and other. The case fatality rates ranged from 8–40% [crude rate 15% (208/1382)] in studies that reported deaths, and among the survivors 4–14% [crude rate 9% (9/98)] had long-term sequelae (limb amputation, hearing loss, or neurological impairment) in studies that reported this outcome.

DISCUSSION

This review shows that the symptoms and signs of MenW IMD are nonspecific, regardless of whether the final clinical manifestation is sepsis, meningitis, or a combination of both. Moreover, the final clinical presentation may also include atypical manifestations. Commonly reported symptoms and signs of overt disease caused by MenW across the studies identified included fever, nausea and/or vomiting, cough, sore throat, diarrhea, headache, altered consciousness/mental status, and stiff neck.

Since IMD, irrespective of the causative serogroup, can rapidly progress to life-threatening illness, timely diagnosis is paramount but hampered by the nonspecific nature of the symptoms and signs. A retrospective UK

Table 1 Top ten symptoms reported by MenW IMD cases in studies that reported symptomology for up to 10 cases

Symptom	Number of cases (n = 74)	Source
Fever	42	[33, 35, 38–40, 42–45, 48–50, 52–54, 60, 61, 63, 65–68, 70–75]
Pain[#]	25	[33, 35–37, 39, 41–45, 47–50, 52, 55, 65, 68, 70, 73–75]
Vomiting	15	[33–36, 63, 65, 67, 68, 72–74]
Rash/spots[§]	12	[36, 38, 48, 56, 63–66, 70]
Headache	11	[33, 38, 47, 65, 66, 68, 72, 74]
Diarrhea	10	[34, 36, 43, 48, 67, 68, 73]
Altered consciousness/mental status	9	[38, 40, 49, 63, 65, 66, 68, 73]
Cough	8	[39, 42, 44, 66, 68, 73, 74]
Stiff neck	8	[38, 40, 65, 66, 68, 72, 73]
Low blood pressure	6	[34, 38, 43, 47, 68, 82]
Tachycardia	6	[34, 38, 40, 52, 66, 68]

[#]Includes chest, eye, leg/ankle, hip, knee, and abdomen pain
[§]Maculopapular/petechial/purpuric

Table 2 Top ten symptoms reported by MenW IMD cases among the studies that report symptomology for > 10 cases

Symptom	Crude rate, % (n/M)	Range	Source
Fever	79% (310/393)	36–100%	[77, 78, 80, 84, 87, 89, 90, 94]
Nausea and/or vomiting[#]	44% (36/81)	38–47%	[89, 90]
Vomiting[#]	35% (118/336)	14–68%	[76, 78, 80, 84, 87, 94]
Cough	28% (112/404	7–57%	[76–78, 84, 87, 90]
Sore throat	26% (76/291)	13–34%	[76, 84, 87, 90]
Headache	25% (84/333)	7–50%	[76, 80, 84, 87, 90, 94]
Diarrhea	22% (81/368)	8–47%	[76, 78, 84, 87, 89, 94]
Altered consciousness/mental status	18% (52/291)	7–38%	[76, 84, 87, 90]
Stiff neck	18% (33/185)	7–54%	[76, 84, 87, 90]
Nausea[#]	18% (29/157)	7–20%	[84, 87]

Proportions shown are based on studies that reported these outcomes
n number of cases with the symptom, M number of cases in the studies that report the symptom
[#]Nausea and vomiting were reported separately or combined in some studies

Table 3 Clinical manifestations reported for MenW IMD cases among studies that report data for up to ten cases

Symptom	Number of cases (n = 74)	Source
Sepsis	27	[33–36, 41, 42, 47–49, 52, 56, 57, 59, 60, 64–66, 68, 70, 72, 73, 81, 82]
Meningitis	17	[63, 65–69, 71, 73, 81]
Sepsis and meningitis	4	[40, 66, 81]
Arthritis	10	[37, 39, 44, 50, 51, 53–55, 69]
Bacteremic pneumonia	4	[68, 75]
Other[#]	8	[38, 43, 45, 46, 58, 62, 74]

[#]Other manifestations include: pericarditis, myocarditis, bacteremic conjunctivitis

Table 4 Clinical manifestations reported for MenW IMD cases among the studies that reported data for > 10 cases

Symptom	Crude rate, % (n/M)	Range	Source
Sepsis	45% (669/1481)	15–83%	[29, 31, 76, 78, 79, 83, 84, 87–92, 95]
Meningitis[‡]	29% (419/1434)	5–72%	[29, 31, 76, 78–80, 83, 87, 88, 90–92, 95]
Sepsis and meningitis	17% (168/991)	6–74%	[29, 31, 79, 83, 84, 86–88, 91, 92]
Bacteremic pneumonia[§]	13% (109/850)	4–24%	[29, 30, 76, 78, 83–87, 90]
Arthritis[§]	5% (115/2460)	1–15%	[29, 30, 32, 76, 78, 83–88, 90, 95]
Other[#§]	11% (141/1328)	1–24%	[29–31, 76, 78, 80, 83–87, 91]

Proportions shown are based on studies that reported these manifestations and which reported all available IMD cases [i.e., excluding studies that only focused on those with a specific manifestation (e.g., excluding studies that focused on those with meningitis only [77, 86])]. Cases reported may have experienced more than one manifestation in some studies. As such, the proportions shown are not based on a common denominator (i.e., do not add up to 100%)

n, number of cases with the symptom; M, number of cases in the studies that report the symptom

[‡]With/without meningococcemia

[§]Manifestation with/without sepsis or meningitis

[#]Other manifestations include: pharyngitis, epiglottitis, supraglottitis, tonsillitis, conjunctivitis, cellulitis, and pericarditis

analysis of a survey assessing the course of illness before hospital admission of children and adolescents (n = 448) with meningococcal disease found that about half were sent back home after the first consultation with their general practitioners (GPs) [96]. Similarly, a retrospective analysis of a French national public health insurance database assessing care pathways in IMD reported that in the three days prior to hospital admission (n = 995), 28.2% had been sent home following a previous consultation with a physician [97]. Thus, delays seem inevitable unless the diagnostic value of the nonspecific symptoms and signs in identifying those with serious infections can be better ascertained to enable accurate assessment and timely management.

Among the studies identified that compared the clinical features of MenW disease with those caused by other meningococcal serogroups, a prospective analysis of IMD cases ($n = 565$) reported to the Dutch IMD surveillance system between 1 January 2015 and 30 June 2018 found that patients with MenW were more often diagnosed with septicemia/septic shock without meningitis (46%) and less often with meningitis without septicemia/septic shock (17%) than other serogroups [87]. Pneumonia (19%) or arthritis (12%) without septicemia or meningitis were highest in those with MenY and MenC IMD, respectively. Symptoms of petechiae and neck stiffness, were highest among MenB cases (38% and 33%, respectively) and relatively low among MenW (9% and 12%), and MenY (14% and 8%) IMD cases. However, both MenW and MenY cases more often had symptoms such as diarrhea (19% and 12%, respectively), as well as cough (19% and 14%), shortness of breath (18% and 17%), pain while breathing (5% and 8%), or a sore throat (21% and 14%) than MenB cases.

Similar results were reported in a retrospective analysis of epidemiologic data from the Taiwanese national surveillance system between 2001 and 2003 ($n = 115$) [90]: bacteremia without meningitis (52%) accounted for most MenW cases, although the remainder were meningitis (48%). Although sore throat and cough were the only symptoms reported more frequently with MenW cases than with the other serogroups, the differences were not statistically significant. However, a significantly higher prevalence of pneumonia was found in MenW cases. An analysis of MenB, MenW, and MenY surveillance data obtained in England during 2014 ($n = 340$) in those aged ≥ 5 years also showed that septicemia was more often a diagnoses for MenW cases (53%) compared with other the serogroups (versus 40% and 44%) [29]. In addition, gastrointestinal (which collectively included nausea, vomiting, diarrhea and abdominal pain; 30%) and upper respiratory tract (sore throat, cough, difficulty swallowing and swollen throat; 31%) symptoms were more likely to occur among MenW cases than the other serogroups.

An analysis of strains causing meningococcal septic arthritis cases ($n = 162$) in England and Wales between January 2010 and December 2020 showed that MenW was accountable for 40.9% (66/161) of such cases, but only a small proportion of all MenW cases (5.1%, 66/1291) were septic arthritis (versus 0.8% to 4.9% with other serogroups) [32]. In particular, MenW strains caused the majority (63.0%, 34/54) of septic arthritis cases among children and adolescents (≤ 19 years). Moreover, controlling for age group, regression analyses indicated that MenW was almost six times more likely to cause septic arthritis than MenB [odds ratio: 5.7; 95% confidence interval (CI) 3.7–8.7]. Similarly, MenY and MenC were four and five times more likely to cause septic arthritis than MenB (odds ratios 4.1 [CI 2.5–6.8] and 5.1 [CI 2.9–9.0], respectively). Thus, using MenB as a baseline, MenW appears to cause slightly more cases of septic arthritis than MenY and MenC, but this would need to be confirmed in more comprehensive studies; nonetheless, all these serogroups are more likely to cause septic arthritis than serogroup B.

Interestingly, anecdotal evidence of the ages of the MenW IMD cases reported appears to have changed over time since the earliest publications in 1980's. The first few initial cases reported were mainly adults, and subsequently reported mainly in children and adolescents/young adults from the 1990s through to 2010, and since 2010 across all age groups. The change in ages affected since 2010 appears generally consistent with the reported epidemiology of cases with the lineage "South American UK strain" in the Netherlands and UK, with the first few cases being mainly adults (2010–2012) and the elderly in particular, and then more cases among adolescents (10–19-year-olds in 2012–2013) and children < 5 years old after 2013 [98].

The main limitation of our review was related to the limited quality of included reports; these were predominately single-case/limited case series and retrospective studies. We cannot exclude the possibility of missing reports and incomplete/variable description of the symptoms across studies, or the possibility of double counting reported manifestations where

country surveillance data was presented across overlapping periods (or across studies). Another limitation was that only articles published in English or those that had an English abstract were considered. Inclusion of reports published in other languages may avoid potentially missing key information or introducing bias. Vaccination history of the reported cases was generally not reported and as such the impact of vaccination on symptom/severity profile in cases of breakthrough disease is unclear. In particular, quadrivalent meningococcal polysaccharide-conjugate vaccines (MenACWY) were introduced over a decade ago in some countries (targeting a wide age range), in part due to increase in MenW IMD cases [99], and as such, the symptoms and signs reported may differ in patients according to residual immunity after vaccination. Additionally, the assessment of symptomology/clinical features by MenW genotype was beyond the scope of the current review; it is possible that the clinical presentation may differ by MenW genotype encountered [100].

In conclusion, the clinical presentation of patients with MenW IMD is heterogeneous. Commonly reported symptoms included fever, vomiting, cough, headache, diarrhea, altered consciousness/mental status, and stiff neck, and are generally consistent with the typical IMD manifestations of sepsis and meningitis. Atypical manifestations such as pneumonia, arthritis, and other (e.g., pharyngitis, epiglottitis, supraglottitis, tonsillitis, conjunctivitis) constitute a sizable proportion of reported cases. Clinicians need to be aware of these atypical manifestations of IMD in regions where MenW is known to circulate to ensure timely diagnoses, identification of pathogen, and treatment. Nonetheless, these results further emphasise the importance of disease prevention through timely vaccination with available meningococcal vaccines, given the nonspecific nature of the symptoms and signs of IMD, and the likelihood of treatment delay.

ACKNOWLEDGEMENTS

The authors thank Anirban Sanyal, MSc, PhD, for editorial assistance and manuscript coordination on behalf of Sanofi.

Author Contributions. I.B-G., L.F., and F.C. contributed to concept/design and data selection. R.E.G. contributed to data selection and acquisition. I.B-G., L.F., F.C., T.G., and M.K.T. contributed to the interpretation of the data. All authors critically reviewed the manuscript and approved the final version for submission.

Funding. This work was supported by Sanofi. The sponsor also funded the journal's rapid service fee.

Data Availability. All data generated or analyzed during this study are included in the published article (and its Supplementary Information files).

Declarations

Conflict of Interest. I.B-G., L.F., and F.C. are employees of Sanofi and may hold shares and/or stock options in the company. R.E.G. is an employee of inScience Communications, Springer Healthcare Ltd, UK, which was contracted by Sanofi to undertake the literature search and provide editorial assistance. M.K.T. performs contract work for the Institut Pasteur funded by GSK, Pfizer, and Sanofi, and has a patent (NZ630133A) with GSK "vaccines for serogroup X meningococcus" issued.

Ethical Approval. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

REFERENCES

1. World Health Organization. Meningitis. 2022; [cited 2022 Aug 1]. Available at: https://www.who.int/health-topics/meningitis#tab=tab_1.

2. European Centre for Disease Prevention and Control. Factsheet about meningococcal disease. 2022; [cited 2022 Aug 1]. Available at: https://www.ecdc.europa.eu/en/meningococcal-disease/factsheet.

3. He F, Yang HM, Li GM, et al. *Neisseria meningitidis* carriage and risk factors among teenagers in Suizhou city in China. Epidemiol Infect. 2020;148: e227. https://doi.org/10.1017/S0950268820002113.

4. Rosenstein NE, Perkins BA, Stephens DS, Popovic T, Hughes JM. Meningococcal disease. N Engl J Med. 2001;344:1378–88. https://doi.org/10.1056/NEJM200105033441807.

5. European Centre for Disease Prevention and Control. Invasive meningococcal disease. In: ECDC. Annual Epidemiological Report for 2018. Stockholm: ECDC; 2022; [cited 2023 Aug 28]. Available at: https://www.ecdc.europa.eu/sites/default/files/documents/AER-Invasive-meningococcal-disease-2018.pdf.

6. Lemee L, Hong E, Etienne M, et al. Genetic diversity and levels of expression of factor H binding protein among carriage isolates of *Neisseria meningitidis*. PLoS ONE. 2014;9: e107240. https://doi.org/10.1371/journal.pone.0107240.

7. Mbaeyi S, Duffy J and McNamara LA. Meningococcal disease. In: Hall E, Wodi AP, J. H, et al. (eds) Centers for disease control and prevention epidemiology and prevention of vaccine-preventable diseases 14th ed. Washington, D.C. Public Health Foundation, 2021, pp.207–224.

8. Voss SS, Nielsen J, Valentiner-Branth P. Risk of sequelae after invasive meningococcal disease. BMC Infect Dis. 2022;22:148. https://doi.org/10.1186/s12879-022-07129-4.

9. Whittaker R, Dias JG, Ramliden M, et al. The epidemiology of invasive meningococcal disease in EU/EEA countries, 2004–2014. Vaccine. 2017;35: 2034–41. https://doi.org/10.1016/j.vaccine.2017.03.007.

10. Harrison OB, Claus H, Jiang Y, et al. Description and nomenclature of *Neisseria meningitidis* capsule locus. Emerg Infect Dis. 2013;19:566–73. https://doi.org/10.3201/eid1904.111799.

11. Pelton SI. The global evolution of meningococcal epidemiology following the introduction of meningococcal vaccines. J Adolesc Health. 2016;59: S3–11. https://doi.org/10.1016/j.jadohealth.2016.04.012.

12. Nuttens C, Findlow J, Balmer P, Swerdlow DL, Tin TinHtar M. Evolution of invasive meningococcal disease epidemiology in Europe, 2008 to 2017. Euro Surveill. 2022. https://doi.org/10.2807/1560-7917.ES.2022.27.3.2002075.

13. Li J, Shao Z, Liu G, et al. Meningococcal disease and control in China: findings and updates from the global meningococcal initiative (GMI). J Infect. 2018;76:429–37. https://doi.org/10.1016/j.jinf.2018.01.007.

14. Brueggemann AB, van Jansen Rensburg MJ, Shaw D, et al. Changes in the incidence of invasive disease due to *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Neisseria meningitidis* during the COVID-19 pandemic in 26 countries and territories in the Invasive Respiratory Infection Surveillance Initiative: a prospective analysis of surveillance data. Lancet Digit Health. 2021;3:e360–70. https://doi.org/10.1016/S2589-7500(21)00077-7.

15. Evans JR, Artenstein MS, Hunter DH. Prevalence of meningococcal serogroups and description of three new groups. Am J Epidemiol. 1968;87:643–6. https://doi.org/10.1093/oxfordjournals.aje.a120854.

16. Taha MK, Achtman M, Alonso JM, et al. Serogroup W135 meningococcal disease in Hajj pilgrims. Lancet. 2000;356:2159. https://doi.org/10.1016/S0140-6736(00)03502-9.

17. Mayer LW, Reeves MW, Al-Hamdan N, et al. Outbreak of W135 meningococcal disease in 2000: not emergence of a new W135 strain but clonal expansion within the electophoretic type-37 complex. J Infect Dis. 2002;185:1596–605. https://doi.org/10.1086/340414.

18. Lucidarme J, Hill DM, Bratcher HB, et al. Genomic resolution of an aggressive, widespread, diverse and expanding meningococcal serogroup B C and W lineage. J Infect. 2015;71:544–52. https://doi.org/10.1016/j.jinf.2015.07.007.

19. Traore Y, Njanpop-Lafourcade BM, Adjogble KL, et al. The rise and fall of epidemic *Neisseria meningitidis* serogroup W135 meningitis in Burkina Faso, 2002–2005. Clin Infect Dis. 2006;43:817–22. https://doi.org/10.1086/507339.

20. Caugant DA, Kristiansen PA, Wang X, et al. Molecular characterization of invasive meningococcal isolates from countries in the African meningitis belt before introduction of a serogroup A conjugate vaccine. PLoS ONE. 2012;7: e46019. https://doi.org/10.1371/journal.pone.0046019.

21. Collard JM, Issaka B, Zaneidou M, et al. Epidemiological changes in meningococcal meningitis in Niger from 2008 to 2011 and the impact of vaccination. BMC Infect Dis. 2013;13:576. https://doi.org/10.1186/1471-2334-13-576.

22. Barra GN, Araya PA, Fernandez JO, et al. Molecular characterization of invasive Neisseria meningitidis strains isolated in Chile during 2010–2011. PLoS ONE. 2013;8: e66006. https://doi.org/10.1371/journal.pone.0066006.

23. Efron AM, Sorhouet C, Salcedo C, Abad R, Regueira M, Vazquez JA. W135 invasive meningococcal strains spreading in South America: significant increase in incidence rate in Argentina. J Clin Microbiol. 2009;47:1979–80. https://doi.org/10.1128/JCM.02390-08.

24. Lemos AP, Harrison LH, Lenser M, Sacchi CT. Phenotypic and molecular characterization of invasive serogroup W135 *Neisseria meningitidis* strains from 1990 to 2005 in Brazil. J Infect. 2010;60:209–17. https://doi.org/10.1016/j.jinf.2009.11.014.

25. Krone M, Gray S, Abad R, et al. Increase of invasive meningococcal serogroup W disease in Europe, 2013 to 2017. Euro Surveill. 2019;24(14):1800245. https://doi.org/10.2807/1560-7917.ES.2019.24.14.1800245.

26. Lucidarme J, Scott KJ, Ure R, et al. An international invasive meningococcal disease outbreak due to a novel and rapidly expanding serogroup W strain, Scotland and Sweden, July to August 2015. Euro Surveill. 2016;21(45):30395. https://doi.org/10.2807/1560-7917.ES.2016.21.45.30395.

27. Birrell MT, Strachan J, Holmes NE, et al. Clinical manifestations of invasive meningococcal disease in Victoria with the emergence of serogroup W and serogroup Y *Neisseria meningitidis*. Int Med J. 2021;51:390–7. https://doi.org/10.1111/imj.14771.

28. Stinson C, Burman C, Presa J, Abalos M. Atypical presentation of invasive meningococcal disease caused by serogroup W meningococci. Epidemiol Infect. 2020;148: e12. https://doi.org/10.1017/S0950268819002152.

29. Campbell H, Andrews N, Parikh S, et al. Variable clinical presentation by the main capsular groups causing invasive meningococcal disease in England. J Infect. 2020;80:182–9. https://doi.org/10.1016/j.jinf.2019.11.001.

30. Martin NV, Ong KS, Howden BP, et al. Rise in invasive serogroup W meningococcal disease in Australia 2013–2015. Commun Dis Intell Q Rep. 2016;40:E454–9.

31. Parikh SR, Campbell H, Gray SJ, et al. Epidemiology, clinical presentation, risk factors, intensive care admission and outcomes of invasive meningococcal disease in England, 2010–2015. Vaccine. 2018;36:3876–81. https://doi.org/10.1016/j.vaccine.2018.02.038.

32. Gyamfi-Brobbey G, Clark SA, Campbell H, et al. An analysis of *Neisseria meningitidis* strains causing meningococcal septic arthritis in England and Wales: 2010–2020. J Infect. 2022;85:390–6. https://doi.org/10.1016/j.jinf.2022.07.019.

33. Cheddani H, Desgabriel AL, Coffin E, et al. No neck pain: meningococcemia. Am J Med. 2018;131:37–40. https://doi.org/10.1016/j.amjmed.2017.08.002.

34. Bozan G, Kilic O, Cetin N, et al. A severe course of serogroup W meningococcemia in a patient with infantile nephropathic cystinosis. Hum Vaccin Immunother. 2020;16:2787–8. https://doi.org/10.1080/21645515.2020.1742508.

35. Russcher A, Fanoy E, van Olden GDJ, Graafland AD, van der Ende A, Knol MJ. Necrotising fasciitis as atypical presentation of infection with emerging *Neisseria meningitidis* serogroup W (MenW) clonal complex 11, the Netherlands, March 2017. Euro Surveill. 2017;22(23):30549. https://doi.org/10.2807/1560-7917.ES.2017.22.23.30549.

36. Houweling BM, van Meurs SJ, Versluis J, Grewal S, Verkaik NJ, van den Akker JPC. Massive diarrhoea and sepsis due to an infection with *Neisseria meningitidis* serogroup W. Neth J Med. 2019;77:116–8.

37. Skoczyńska A, Kadłubowski M, Dąbrowska-Parfianowicz D, Hołownia-Puczel E, Waśko I, Hryniewicz W. Primary meningococcal arthritis. Am J Case Rep. 2010;11:2.

38. Shinha T, Fujita H. Pericarditis due to *Neisseria meningitidis* serogroup W135. IDCases. 2018;12: 53–5. https://doi.org/10.1016/j.idcr.2018.02.009.

39. Dapueto G, Barrios P, Zabala C, Peluffo G, Giachetto G. Primary meningococcal arthritis of the hip due to serogroup W in a pediatric patient. Bol Med Hosp Infant Mex. 2021;78:631–5. https://doi.org/10.24875/BMHIM.20000375.

40. Mori N, Hayashi T, Nakamura H, Takahashi H. Meningococcal meningitis with neurological complications and meningococcemia due to serogroup W sequence type 11 complex. J Infect Chemother. 2018;24:398–400. https://doi.org/10.1016/j.jiac.2017.12.005.

41. Pletschette Z, Grimaldi D, De Groote E. Meningococcal necrotizing cellulitis in a patient following gastric bypass surgery. Acta Cunica Belgica. 2020;2: 25–6.

42. Yamamoto K, Kato Y, Shindo T, et al. Meningococcemia due to the 2000 Hajj-associated outbreak strain (Serogroup W-135 ST-11) with immunoreactive complications. Jpn J Infect Dis. 2013;66:443–5. https://doi.org/10.7883/yoken.66.443.

43. Aung M, Raith E, Williams E, Burrell AJ. Severe meningococcal serogroup W sepsis presenting as myocarditis: a case report and review of literature. J Intensive Care Soc. 2019;20:182–6. https://doi.org/10.1177/1751143718794127.

44. Brawley RL, Barson WJ, Palmer R, Hilty MD, Koranyi K. Acute septic arthritis caused by *Neisseria meningitidis* serogroup W-135. South Med J. 1980;73:395–6. https://doi.org/10.1097/00007611-198003000-00041.

45. Beltrami D, Guilcher P, Longchamp D, Crisinel PA. Meningococcal serogroup W135 epiglottitis in an adolescent patient. BMJ Case Rep. 2018. https://doi.org/10.1136/bcr-2017-223038.

46. Mazankova LN, Samitova ER, Khoroid NV, Ermakova MN, Cheburkin AA. Rare generalized form of meningococcal disease caused by *Neisseria meningitidis* serogroup W. J Infektologii. 2020;12:111–8.

47. Platten M, Aladellie L. *Neisseria meningitidis* serogroup W(P15–2) sepsis presenting with myopericarditis in an elderly previously healthy male. IDCases. 2021;25: e01238. https://doi.org/10.1016/j.idcr.2021.e01238.

48. Lopez M, Maas JJ, Elzo Kraemer CV. Life saving strategy in a new strain meningococcal invasive disease. Perfusion (Germany). 2019;34:98–9.

49. Gaschignard J, Hassani N, El Sissy C, et al. Delayed generalized necrotic purpuric rash in a C6-deficient 12-year-old girl treated for group w meningococcal disease. Pediatr Infect Dis J. 2018;37:1014–5. https://doi.org/10.1097/INF.0000000000001966.

50. Fidder AR, de Hartog B, Faber T. Child with serogroup W135 primary meningococcal septic arthritis. BMJ Case Rep. 2019;12(10): e229510. https://doi.org/10.1136/bcr-2019-229510.

51. Bisgaard AK, Fagerberg SK, Hjort U. Primary septic arthritis is a rare, atypical manifestation of invasive meningococcal disease. Ugeskr Laeger. 2017;179(48):V09170693.

52. Keeley AJ, Hammersley D, Dhamrait SS. A case of myopericarditis caused by *Neisseria meningitidis* W135 serogroup with protracted inflammatory syndrome. Clin Med (Lond). 2018;18:253–5. https://doi.org/10.7861/clinmedicine.18-3-253.

53. Hachisu Y, Kanai M, Kamiya H, et al. Transmission of *N. meningitidis* serogroup W, ST-11 during an international flight. Open Forum Infect Dis. 2017;4: S239.

54. McMullan B. An infant with meningococcal arthritis of the hip. J Paediatr Child Health. 2009;45:762–3. https://doi.org/10.1111/j.1440-1754.2009.01607.x.

55. Apfalter P, Horler R, Nehrer S. *Neisseria meningitidis* serogroup W-135 primary monarthritis of the hip in an immunocompetent child. Eur J Clin Microbiol Infect Dis. 2000;19:475–6. https://doi.org/10.1007/s100960000289.

56. Friedl C, Hackl G, Schilcher G, Rosenkranz AR, Eller K, Eller P. Waterhouse-Friderichsen syndrome due to *Neisseria meningitidis* infection in a young adult with thrombotic microangiopathy and eculizumab treatment: case report and review of management. Ann Hematol. 2017;96:879–80. https://doi.org/10.1007/s00277-017-2951-8.

57. Gilbey T, McIver C, Brandenburg U, et al. Suspected materno-fetal transmission of *Neisseria meningitidis* serogroup W clonal complex 11 causing early-onset neonatal sepsis. Open Forum Infect Dis. 2020;7:39. https://doi.org/10.1093/ofid/ofaa039.

58. Iversen MS, Hoffmann S, Lind K, Dungu A, Johannesen TB, Holzknecht BJ. Spontaneous bacterial peritonitis and bacteraemia caused by meningococci serogroup W clonal complex 11. Ugeskr Læger. 2018;180:V11170841.

59. Puleston R, Beck C, Tahir M, et al. An unusual transmission event of *Neisseria meningitidis* serogroup W135 type 2a in a healthcare setting, England, 2012. Euro Surveill. 2012;17(44):20308.

60. Pratt JJ, Connell TG, Bekhit E, Crawford NW. Splenic cyst and its management in a 21-month-old boy: a rare complication of invasive meningococcal disease. BMJ Case Rep. 2018. https://doi.org/10.1136/bcr-2018-224613.

61. Reina G, Camacho E, Turiño JD, Pérez MD, Miranda C. Infection due to *Neisseria meningitidis* serogroup W-135. Clin Microbiol Newsl. 2005;27:48–9.

62. Ouzts HG, Newland H. *Neisseria meningitidis* serogroup W-135 disease in adults. JAMA. 1982;247:1810.

63. Mularski A, Zaba C. Fatal meningococcal meningitis in a 2-year-old child: a case report. World J Clin Cases. 2019;7:636–41. https://doi.org/10.12998/wjcc.v7.i5.636.

64. Duron S, Martinaud C, Lacassagne D, Koeck JL. A fatal case of invasive infection caused by W135 *Neisseria meningitidis* in a vaccinated French soldier. Mil Med. 2016;181:e1702–5. https://doi.org/10.7205/MILMED-D-15-00448.

65. Turhan V, Acar A, Kilic A, et al. Meningococcemia and meningitis due to *Neisseria meningitidis* W135 developed in two cases vaccinated with bivalent (A/C) meningococcal vaccine. Mikrobiyol Bul. 2010;44:473–8.

66. Jo YM, Bae SM, Kang YH. Cluster of serogroup W-135 meningococcal disease in 3 military recruits. J Korean Med Sci. 2015;30:662–5. https://doi.org/10.3346/jkms.2015.30.5.662.

67. Baldwin L, Khan M, Kallappa C. All diarrhoea and vomiting in children is not gastroenteritis. Pediatr Cogent Med. 2017;4:5.

68. Brandstetter RD, Blair RJ, Roberts RB. *Neisseria meningitidis* serogroup W 135 disease in adults. JAMA. 1981;246:2060–1.

69. Faye A, Marianni-Kurkdjian P, Taha MK, Soussan V, Bingen E, Bourrillon A. Meningococcal disease due to *Neisseria meningitidis* serogroup W135 in children. Clinical aspects and outcome. Presse Med. 2004;33:654–7. https://doi.org/10.1016/s0755-4982(04)98708-8.

70. Bassi C, Taha MK, Merle C, et al. A cluster of invasive meningococcal disease (IMD) caused by *Neisseria meningitidis* serogroup W among university students, France, February to May 2017. Euro Surveill. 2017;22(28):30574. https://doi.org/10.2807/1560-7917.ES.2017.22.28.30574.

71. Stefanelli P, Fazio C, Neri A, et al. Imported and indigenous cases of invasive meningococcal disease W:P1.5,2:F1–1: ST-11 in migrants' reception centers. Italy, June–November 2014. Adv Exp Med Biol 2016; 897: 81–83. DOI: https://doi.org/10.1007/5584_2015_5006.

72. He B, Jia Z, Zhou H, et al. CC4821 serogroup W meningococcal disease in China. Int J Infect Dis. 2014;29:113–4. https://doi.org/10.1016/j.ijid.2014.08.022.

73. Joiner KT, Odugbemi TO, Afolabi JK. Disease in children due to serogroup W-135 *Neisseria meningitidis*. Afr J Med Med Sci. 1990;19:1–3.

74. El Bashir H, Klaber R, El Baki A, Booy R. W135 meningococcal pericarditis: report of two cases and review of the literature. Pediatr Infect Dis J. 2004;23:969–70. https://doi.org/10.1097/01.inf.0000141731.98250.e3.

75. Witt D, Olans RN. Bacteremic W-135 meningococcal pneumonia. Am Rev Respir Dis. 1982;125:255–7. https://doi.org/10.1164/arrd.1982.125.2.255.

76. Sall O, Stenmark B, Jacobsson S, et al. Atypical presentation of *Neisseria meningitidis* serogroup W disease is associated with the introduction of the 2013 strain. Epidemiol Infect. 2021;149: e126. https://doi.org/10.1017/S0950268821001035.

77. Osuorah D, Shah B, Manjang A, Secka E, Ekwochi U, Ebenebe J. Outbreak of serotype W135 *Neisseria meningitidis* in central river region of the Gambia between February and June 2012: a hospital-based review of paediatric cases. Niger J Clin Pract. 2015;18:41–7. https://doi.org/10.4103/1119-3077.146977.

78. Sudbury EL, O'Sullivan S, Lister D, Varghese D, Satharasinghe K. Case manifestations and public health response for outbreak of meningococcal W disease, Central Australia, 2017. Emerg Infect Dis. 2020;26:1355–63. https://doi.org/10.3201/eid2607.181941.

79. Lee SO, Ryu SH, Park SJ, Ryu J, Woo JH, Kim YS. Meningococcal disease in the republic of Korea army: incidence and serogroups determined by PCR. J Korean Med Sci. 2003;18:163–6. https://doi.org/10.3346/jkms.2003.18.2.163.

80. Tsolia MN, Theodoridou M, Tzanakaki G, et al. Invasive meningococcal disease in children in Greece: comparison of serogroup A disease with disease caused by other serogroups. Eur J Clin Microbiol Infect Dis. 2006;25:449–56. https://doi.org/10.1007/s10096-006-0155-6.

81. Tuan PL, Li WC, Huang YC, Chiu CH, Lin TY. Invasive pediatric *Neisseria meningitidis* infections. J Microbiol Immunol Infect. 2009;42:427–32.

82. Hansman D. Meningococcal disease in South Australia: incidence and serogroup distribution

1971–1980. J Hyg (Lond). 1983;90:49–54. https://doi.org/10.1017/s0022172400063828.

83. Ladhani SN, Beebeejaun K, Lucidarme J, et al. Increase in endemic *Neisseria meningitidis* capsular group W sequence type 11 complex associated with severe invasive disease in England and Wales. Clin Infect Dis. 2015;60:578–85. https://doi.org/10.1093/cid/ciu881.

84. Campbell H, Parikh SR, Borrow R, Kaczmarski E, Ramsay ME, Ladhani SN. Presentation with gastrointestinal symptoms and high case fatality associated with group W meningococcal disease (MenW) in teenagers, England, July 2015 to January 2016. Euro Surveill. 2016. https://doi.org/10.2807/1560-7917.ES.2016.21.12.30175.

85. Vienne P, Ducos-Galand M, Guiyoule A, et al. The role of particular strains of *Neisseria meningitidis* in meningococcal arthritis, pericarditis, and pneumonia. Clin Infect Dis. 2003;37:1639–42. https://doi.org/10.1086/379719.

86. Matsika-Claquin MD, Perrocheau A, Taha MK, et al. Meningococcal W135 infection epidemics associated with pilgrimage to Mecca in 2000. Presse Med. 2001;30:1529–34.

87. Loenenbach AD, van der Ende A, de Melker HE, Sanders EAM, Knol MJ. The clinical picture and severity of invasive meningococcal disease serogroup W compared with other serogroups in the Netherlands, 2015–2018. Clin Infect Dis. 2020;70:2036–44. https://doi.org/10.1093/cid/ciz578.

88. Parikh SR, Campbell H, Beebeejaun K, et al. Meningococcal group W disease in infants and potential prevention by vaccination. Emerg Infect Dis. 2016;22:1505–7. https://doi.org/10.3201/eid2208.160128.

89. Moreno G, Lopez D, Vergara N, Gallegos D, Advis MF, Loayza S. Clinical characterization of cases with meningococcal disease by W135 group in Chile, 2012. Rev Chilena Infectol. 2013;30:350–60. https://doi.org/10.4067/S0716-10182013000400002.

90. Wang JL, Liu DP, Yen JJ, et al. Clinical features and outcome of sporadic serogroup W135 disease Taiwan. BMC Infect Dis. 2006;6:7. https://doi.org/10.1186/1471-2334-6-7.

91. Hovmand N, Lundbo LF, Kronborg G, et al. Recent increased incidence of invasive serogroup W meningococcal disease: a retrospective observational study. Int J Infect Dis. 2021;108:582–7. https://doi.org/10.1016/j.ijid.2021.05.086.

92. Spanjaard L, Bol P, de Marie S, Zanen HC. Association of meningococcal serogroups with the course of disease in the Netherlands, 1959–83. Bull World Health Organ. 1987;65:861–8.

93. Guiddir T, Gros M, Hong E, et al. Unusual initial abdominal presentations of invasive meningococcal disease. Clin Infect Dis. 2018;67:1220–7. https://doi.org/10.1093/cid/ciy257.

94. Bethea J, Makki S, Gray S, MacGregor V, Ladhani S. Clinical characteristics and public health management of invasive meningococcal group W disease in the East Midlands region of England, United Kingdom, 2011 to 2013. Euro Surveill. 2016. https://doi.org/10.2807/1560-7917.ES.2016.21.24.30259.

95. von Gottberg A, du Plessis M, Cohen C, et al. Emergence of endemic serogroup W135 meningococcal disease associated with a high mortality rate in South Africa. Clin Infect Dis. 2008;46:377–86. https://doi.org/10.1086/525260.

96. Thompson MJ, Ninis N, Perera R, et al. Clinical recognition of meningococcal disease in children and adolescents. Lancet. 2006;367:397–403. https://doi.org/10.1016/S0140-6736(06)67932-4.

97. Weil-Olivier C, Taha MK, Bouee S, et al. Care pathways in invasive meningococcal disease: a retrospective analysis of the French national public health insurance database. Hum Vaccin Immunother. 2022;18:2021764. https://doi.org/10.1080/21645515.2021.2021764.

98. Knol MJ, Hahne SJM, Lucidarme J, et al. Temporal associations between national outbreaks of meningococcal serogroup W and C disease in the Netherlands and England: an observational cohort study. Lancet Public Health. 2017;2:e473–82. https://doi.org/10.1016/S2468-2667(17)30157-3.

99. Presa J, Findlow J, Vojicic J, Williams S, Serra L. Epidemiologic trends, global shifts in meningococcal vaccination guidelines, and data supporting the use of menACWY-TT vaccine: a review. Infect Dis Ther. 2019;8:307–33. https://doi.org/10.1007/s40121-019-0254-1.

100. Deghmane AE, Haeghebaert S, Hong E, Jousset A, Barret AS, Taha MK. Emergence of new genetic lineage, ST-9316, of *Neisseria meningitidis* group W in Hauts-de-France region, France 2013–2018. J Infect. 2020;80:519–26. https://doi.org/10.1016/j.jinf.2020.01.020.

Publisher's Note