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How to assess the severity of bronchiolitis epidemics? Application of the Moving Epidemic Method in Nouvelle-Aquitaine, France from 2017 to 2023

Caroline Couturier[1], Pascal Vilain[1*], Lindsay S. Cooley[1] and Laurent Filleul[1]

Abstract

Background In France, early detection of bronchiolitis epidemics relies on a multi-source surveillance system. However, this system is unable to measure epidemic severity in real time. Such information would enable faster alerts to decision-makers and medical facilities, allowing healthcare provision to be adapted more effectively. This additional information would provide healthcare decision-makers and care structures to be alerted more quickly and to adapt their healthcare provision in a reactive way. In this context, we conducted a study to assess the severity of bronchiolitis epidemics in children under two years of age, from 2017/18 to 2022/23, in Nouvelle-Aquitaine, France.

Methods The Moving Epidemic Method (MEM) was used to assess the severity of bronchiolitis epidemics, based on three indicators, obtained from three data sources: (1) virus transmissibility, using data from the SOS Medecins network; (2) impact on the hospital system, assessed via emergency departments (ED) data and (3) gravity, using hospital data. Epidemic thresholds and intensity levels were determined by estimating the parameters of MEM.

Results The 2020/21 epidemic was delayed and less severe compared to preceding seasons (2017–2020) across all indicators. In contrast, the 2021/22 and 2022/23 epidemics began early, with prolonged durations. Notably, the 2022/23 epidemic was particularly severe in terms of its impact on the hospital system.

Conclusions The intensity of bronchiolitis epidemics in Nouvelle-Aquitaine (2017–2023) was assessed using MEM. This method is a simple, rapid and effective tool for guiding public health interventions.

Keywords Bronchiolitis, Epidemic, Severity assessment, Moving epidemic method

Background

Bronchiolitis is a seasonal viral infection of the respiratory system. Each winter in France it infects more than a third of children under two years of age [1]. The primary causal agent is the respiratory syncytial virus (RSV), responsible for 60% to 80% of cases, but other viruses also contribute, including rhinovirus (over 25% of cases), bocavirus, metapneumovirus, parainfluenza virus and adenovirus [2].

Bronchiolitis typically persists for 1 to 2 weeks, following an incubation period of 2 to 8 days. Symptoms include cough, runny nose, and fever, and person-to-person transmission occurs via saliva, respiratory droplets from coughing and sneezing, and contaminated hands and objects [3]. In severe cases, hospitalisation or even intensive care is required when children struggle to eat sufficiently or require oxygen therapy [4]. In France,

*Correspondence:
Pascal Vilain
pascal.vilain@santepubliquefrance.fr
[1] Santé Publique France, Cellule en Région Nouvelle-Aquitaine, Bordeaux, France

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2–3% of all infants under one year old are hospitalised for acute bronchiolitis per year [5].

While deaths due to bronchiolitis are rare (estimated case-fatality rate < 0.1% among hospitalized infants) [5], the disease is the leading cause of hospitalisation of newborns every autumn and winter, placing a significant burden on the healthcare system [6, 7].

Since the COVID-19 pandemic, emergency departments in France have faced increased pressure, exacerbating tensions that were already present before the health crisis. The pandemic has highlighted structural difficulties, notably a lack of medical and paramedical staff, leading to temporary or prolonged closures of services in several establishments. Successive epidemic waves have intensified the workload and constraints related to the continuity of care, exacerbating staff exhaustion. The 2022/23 season was marked by a major bronchiolitis epidemic, occurring in a context where many emergency departments were temporarily closed at night.

The current surveillance system can detect bronchiolitis epidemics but cannot assess their intensity in real time. This complementary information would accelerate alerting of healthcare authorities and facilities (hospitals, emergency departments, private practitioners), facilitating adaptation of health care resources.

Internationally, the World Health Organization (WHO) and the European Centre for Disease Prevention and Control (ECDC) have developed the "Moving Epidemic Method" (MEM), which not only detects epidemics, but also measures their severity in near real-time, using intensity levels [8].

The objective of this study was to evaluate the severity of bronchiolitis epidemics in near-real time by adapting the Moving Epidemic Method to local data on children under two years of age in Nouvelle-Aquitaine; France, over the 2017/18 to 2022/23 period.

Method

Data sources

This study utilised historical data from the bronchiolitis surveillance system in Nouvelle-Aquitaine in children under two years of age, over the 2017/18 to 2022/23 period.

The southwestern region of Nouvelle-Aquitaine is the largest administrative region in France, including over 84,000Km^2 and approximately 6 million inhabitants. As in the rest of France, bronchiolitis surveillance primarily relies on a syndromic surveillance system, which includes data from the SOS Medecins and OSCOUR networks. SOS Medecins is a networkof general practitioners (GPs) that provides 24/7 emergency care in the private sector, in the form of home visits or in-clinic consultations [9]. SOS Medecins is a private healthcare entity that is universally accessible but not entirely free. The cost of consultations or home visits is usually covered by health insurance, though out-of-pocket expenses may apply depending on an individual's social coverage status. While there is no formal patient selection, the service may be less frequently used by those lacking health insurance. Every day, data from bronchiolitis-related consultations are transmitted from all five SOS Medecins associations in Nouvelle-Aquitaine to the regional office of the French Public Health Agency [10]. Data collected include the date of in-clinic consultation or home visit, residential postal code, age, sex, patient's health complaints, and medical diagnosis.

The OSCOUR® network (Organisation de la surveillance coordonnée des urgences) collects individual data from computerised medical records completed during emergency (ED) visits. For each visit, the following information is recorded: demographic data (birth date, gender, postcode of residence); administrative data (date and time of admission and discharge, mode of transport, origin, destination after ED visit [hospitalisation, return home]), chief health complaint (free-text entry), and medical diagnoses, coded using the International Classification of Diseases, version 10 (ICD-10) [11]. In Nouvelle-Aquitaine, the OSCOUR® network includes 66 emergency departments, covering 100% of all emergency department visits within the region. Data from visits related to bronchiolitis (coded J21 and subdivisions) are sent to the regional office of the French Public Health Agency daily. EDs are publicly funded and universally accessible, regardless of socio-economic status or insurance coverage. These services are financed through health insurance and public funds, and are generally free for patients. However, co-payments may be required in certain cases, depending on individual insurance policies.

The French National Hospital Discharge database (Programme de Médicalisation des Systèmes d'Information; PMSI) provides exhaustive medico-administrative information about all patients admitted to public and private hospitals in France. For each hospital admission (including intensive care unit admissions), a standard discharge report is recorded. Reports for all ICU admissions for acute bronchiolitis (ICD-10 codes: J21 and subdivisions) for infants aged under 2 years were extracted.

As part of the national surveillance system, the collected data do not contain any identifiable personal information and therefore ethics committee approval for the study was not required.

Moving Epidemic Method

General approach

According to WHO recommendations in the Pandemic Influenza Severity Assessment project [8], the severity of

a bronchiolitis epidemic can be assessed based on three indicators: (1) transmissibility, (2) gravity of disease, (3) impact on the hospital system. In this study, transmissibility was assessed by the proportion of bronchiolitis-related consultations of the SOS Medecins network, while impact on the hospital system was measured via the proportion of hospitalisations for bronchiolitis following ED visits. Gravity was evaluated based on the number of ICU admissions for bronchiolitis according to hospital data.

The MEM aims to model epidemics by establishing both an epidemic threshold, which serves as an early warning signal for future epidemics, and intensity levels, used from comparisons of the intensity of current epidemics with previous seasons.

To dynamically assess the intensity of a current bronchiolitis season, historical data from five previous seasons (2017/18 to 2021/22) were analysed. For each indicator, thresholds were calculated, and applied to each week of data of the current (2022/23) epidemic to determine its intensity in near real-time. Then, the current season was compared with the preceding seasons.

Steps of the MEM approach

The MEM follows a structured approach, as developed by Vega et al. [12]. The first step is to determine the start, duration and end of each historical season using the MEM algorithm. This process involves dividing each season into three distinct phases: pre-epidemic, epidemic, and post-epidemic. To achieve this, the MEM model calculates the optimal duration of each epidemic period using a parameter δ. The optimum duration of the epidemic period (r) for each season is determined as the minimum number of consecutive weeks above the δ. The parameter δ (or i.param in the R package "mem" [13]) varies from 2 to 4% depending on the country. In practical terms, if δ is set at 3, this means that for a week to be considered an epidemic, the proportion of visits for bronchiolitis during that week must represent at least 3% of the season's data. The closer δ is to 2, the greater the sensitivity, i.e. the greater the probability that the week will be considered an epidemic. Conversely, the closer the δ is to 4, the less sensitive the detection will be. Finally, based on the start (k) and duration (r) of the epidemic period, the pre-epidemic period (week 1 to k-1) and the post-epidemic period (k + r to the last week) are identified.

Following definition of the epidemic periods, the epidemic and intensity thresholds are calculated. The epidemic threshold is derived from pre-epidemic data and corresponds to the upper limit of the 95% confidence interval (CI) of the arithmetic mean of the n highest values in each pre-epidemic period, where n = 30 / number of historical seasons. The intensity thresholds are derived from epidemic period data, and correspond to the upper limits (one-side) of the CIs at 40%, 90% and 97.5% of the geometric mean of the 6 highest values in each epidemic period. Finally, five levels of intensity are defined [14]:

- Base level: below the epidemic threshold
- Low intensity level: between the epidemic threshold and the medium intensity threshold (one-sided IC 40%)
- Medium intensity level: between the medium (one-side IC 40%) and high intensity thresholds (one-side IC 90%)
- High intensity level: between the high (one-side IC 90%) and very high intensity thresholds (one-side IC 97.5%)
- Very high intensity: above the very high intensity threshold (one-side IC 97.5%)

Statistical analysis

For current season 2022/2023, the δ value for each indicator was validated by evaluating the performance of the MEM method over the five preceding seasons. To determine the best δ (ranging from 2.0 to 4.0 in 0.1 increments), the sensitivity (Se), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV) and area under the curve value (AUC) were calculated. For each indicator, the δ value with the AUC closest to 1 (maximising both sensitivity and specificity) was selected.

The quality of the MEM classification was assessed by comparing the epidemic and non-epidemic weeks identified by the MEM with those determined by a "gold standard". Here, the gold standard corresponded to the assessments of epidemiologists from the regional office of the French Public Health Agency, using a web-based tool called MASS (Module for the Analysis of SurSaUD and Sentinelles' data) [15]. MASS compiles bronchiolitis data from SOS Medecins and OSCOUR® and computes statistical alarm levels. Each week, MASS generates a maximum of six statistical alarms, which are synthesised into three alert levels:

- "Epidemic" level if the number of alarms is ≥ 1 for both OSCOUR® and SOS Medecins, or ≥ 2 for OSCOUR®;
- "Pre/post epidemic" level if a single alarm is generated from either source
- "No alert" level if no alarms occur.

The epidemiologists also perform a qualitative analysis and may modify the regional alert level based on review of virological data.

Finally, the intensity levels of bronchiolitis epidemics from 2017/18 to 2022/23 were visualised and compared using time series.

Analyses were conducted using R software, specifically the "mem" package [13].

Results

General dynamics of bronchiolitis epidemics

The time series depicting the pre-epidemic, epidemic and post-epidemic periods of bronchiolitis seasons from 2017/18 to 2022/23, as identified by MEM, are presented in Fig. 1.

Bronchiolitis epidemics typically began in mid-November (week 46) and ended by late January (week 5) of the following year. Epidemics lasted 12 to 16 weeks, with the peak typically occurring in early December (week 48). Of the seasons considered, bronchiolitis-related activity was lowest in 2020/21 and highest in 2022/23.

Validation of the parameter δ

The evaluation of the different δ values of the MEM for each indicator is presented in Table 1. For transmissibility, measured as the proportion of bronchiolitis-related visits from the SOS Medecins network, the optimal δ value was 2.2, with an AUC of 0.91, sensitivity of 96%, and specificity of 85%. For the impact indicator, defined as the proportion of hospitalisations for bronchiolitis following ED visits, the best δ retained was 2.8, with an AUC of 0.94, sensitivity of 100% and specificity of 89%. Finally, for the gravity indicator, assessed by the number of bronchiolitis-related ICU admissions from hospital data, the selected δ was 3.5, with an AUC of 0.95, a sensitivity of 92% and a specificity of 97%.

Severity of bronchiolitis epidemics

Considering the six seasons as a whole, the bronchiolitis epidemics of 2020/21 and 2022/23 showed notable deviations in all three MEM indicators, as shown in Fig. 2. The three epidemics from 2017/18 to 2019/20 began in November (around week 44), and lasted 12–19 weeks. In comparison, the 2020/21 season was delayed (by approximately 18 weeks, beginning in March), with a duration shortened by 7–8 weeks. In contrast, both the 2021/22 and 2022/23 seasons were both earlier and prolonged, with epidemics starting in early October (around week 40), and persisting for 16–18 weeks. Across all indicators, epidemic peaks occurred in December (between weeks 47 and 51), except in 2020/21 when the peak occurred in late March (weeks 12 and13).

The 2022/2023 bronchiolitis epidemic was characterised by a very high level of intensity for all three data sources compared with historical seasons.

In contrast, the 2020/2021 bronchiolitis epidemic was characterised by a low level of intensity. For the other seasons, the level of intensity was medium, except for the 2018–2019 season, in which the related bronchiolitis activity in SOS Medecins and EDs reached high and very high levels of intensity respectively.

Discussion

In this study, the Moving Epidemic Method was applied to assess the severity of six bronchiolitis epidemics in Nouvelle-Aquitaine, following validation of the δ values for each indicator. The MEM identified 2022/23 and 2018/19 as the seasons with the highest transmissibility, and 2022/23 as the one with the greatest impact on hospital system. The 2020/21 epidemic was characterised as the least severe, with the weakest transmissibility and hospital system impact. Additionally, the post-pandemic bronchiolitis epidemics started earlier and persisted for longer compared to those occurring prior to the COVID -19 pandemic. The 2022/23 epidemic was particularly early and serious (i.e. very high intensity for ICU admissions for acute bronchiolitis) among children under two years of age. The pandemic likely altered the usual patterns of bronchiolitis epidemics. It has been hypothesised that multiple lockdowns, use of facemasks and strict hygiene measures during the pandemic resulted in decreased exposure to respiratory viruses, leading to a delayed and unusually mild bronchiolitis epidemic in 2020/21 [16, 17]. Furthermore, this diminished exposure may lead to development of an immunity gap, where the immature immune systems of children are unable to build immune memory against viral infections [18]. This likely contributed to an enhanced susceptibility to viruses, and in turn to the early start of seasons 2020/21 and 2022/2023, and the high severity of the 2022/2023 epidemic [19]. Given that the pandemic season 2020/21 showed unusual patterns of bronchiolitis activity, a sensitivity analysis was performed in which this season was replaced by data from 2016/17 and obtained similar results (data not shown).

To our knowledge, this is the first study to assess the severity of bronchiolitis epidemics in near real-time in France. Two previous studies evaluated the severity and seasonality of RSV [20, 21]. However, direct comparison with our findings are challenging due to differences in study periods and methodologies – notably, these studies did not incorporate severity and hospital impact indicators. On the other hand, a recent study applied the MEM to clinical bronchiolitis in children under two years old in primary healthcare in Spain [22] to estimate the epidemic level of seasonal epidemics. Matching our findings, the study reports an alteration in the epidemic pattern during the COVID-19 period: a delayed epidemic of lower

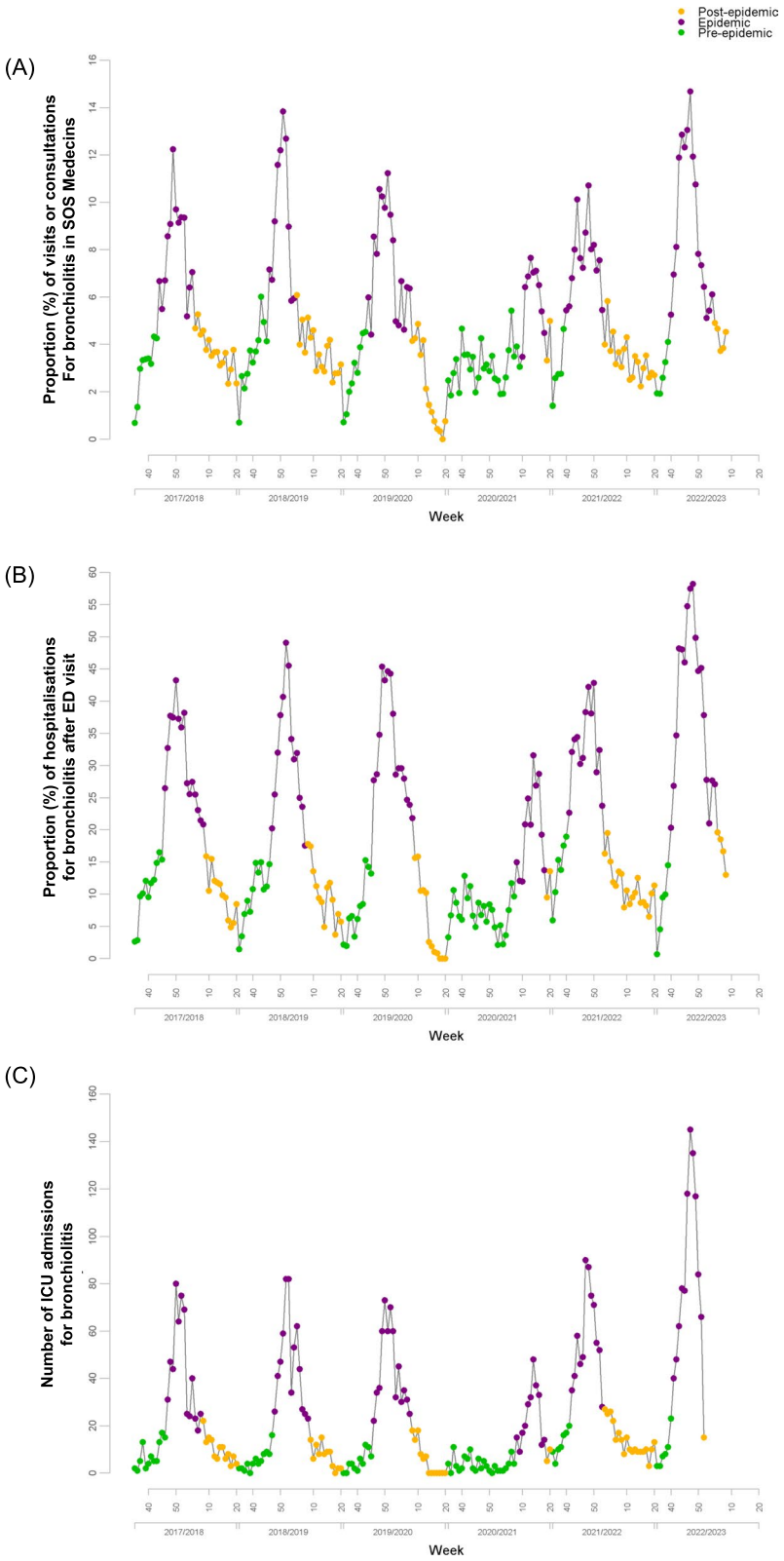


Fig. 1 General dynamics of bronchiolitis epidemics for the 2017/18 to 2022/23 seasons in Nouvelle-Aquitaine, as identified using MEM indicators. **A** Transmissibility, **B** Impact on the hospital system, **C** Gravity

Table 1 Performance of the MEM according to optimal δ values for bronchiolitis epidemics in Nouvelle-Aquitaine

Indicator	Data source	Parameter	Best	Sensibility	Specificity	PPV	NPV	AUC
Transmissibility	SOS Medecins	Proportion of visits or consultations for bronchiolitis	2.2	0.96	0.85	0.70	0.98	0.91
Impact	OSCOUR	Proportion for hospitalisations fron bronchiolitis after a visist to ED	2,8	1	0.89	0.76	1	0.94
Gravity	Hospistal data	Number of ICU admissions for bronchiolitis	3,5	0.92	0.97	0.92	0.97	0.95

intensity, followed by a very high-intensity epidemic in the 2022/2023 season.

The MEM approach was selected for this study due to its robustness and widespread application in multiple European and non-European countries [23–31]. It provides a standardised method to compare epidemic intensity across countries and at the global level. Additionally, MEM can be rapidly implemented to provide timely information to support decision-making by healthcare authorities and establishments [8].

Unlike many studies using MEM [20, 22, 27, 32], our study constructed severity indicators based on three distinct data sources, allowing for a more comprehensive assessment of bronchiolitis epidemics, By integrating these data sources, our analysis provided a holistic view of epidemic intensity, covering both mild and severe cases across the healthcare system.

A key advantage of syndromic data from SOS Medecins and OSCOUR® is that they are updated daily, enabling the near real-time assessment of the epidemic situation and intensity. Furthermore, the hospital database offers comprehensive coverage of all hospital data across France, making it a highly reliable and representative data source.

This study has several limitations. Firstly, the bronchiolitis diagnoses in SOS Medecins and OSCOUR data were not biologically confirmed, potentially causing information bias and under- or over-estimation of the findings. Nevertheless, these syndromic surveillance data provide dynamic, timely insights, and combined with complementary data sources (laboratory virological data, Sentinelles network, etc.) strengthen seasonal bronchiolitis epidemic detection and monitoring.

Secondly, SOS Medecins data are not fully representative of outpatient care, and these associations primarily cover urgent medical consultations rather than the range of standard consultations in general clinical practice. Furthermore, SOS Medecins associations are not located in all departments of the region (5 associations; in 4 out of 12 departments), and primarily serve urban and semi-urban areas. As a result, individuals consulting SOS Medecins for bronchiolitis represent only a subset of the target population, which likely introduces selection bias and underestimates epidemic intensity in terms of transmissibility. To improve the assessment of transmissibility, future study could explore the use of laboratory data pertaining to biologically confirmed cases.

Thirdly, results related to impact on the hospital system should be cautiously interpreted. In 2022, the coding rate for diagnoses was 90% (10% of visits did not received a recorded diagnostic code), which likely led to an underestimation of bronchiolitis-related hospitalisations. Furthermore, since the coding for bronchiolitis in the emergency department visit records is presumptive (without biological confirmation), an information bias may cause over- or under-estimation of bronchiolitis-related hospitalisations and the impact of bronchiolitis on hospital services. Nevertheless, these data are valuable for rapid, near real-time epidemic monitoring.

The proportion of bronchiolitis-related consultations and hospitalisations for bronchiolitis following ED visit is influenced by the level of circulating viruses or other pathologies leading to medical consultations. As a result, the transmissibility and impact of bronchiolitis may be under- or over-estimated depending on the prevalence of co-existing diseases in a given season. This is important to consider when interpreting results using data obtained from the COVID-19 pandemic, during which ED and other medical consultations were globally reduced [33], and the frequencies of many other pathologies (including respiratory viruses) were significantly altered.

Finally, hospital data can't be used to assess the gravity in real time in practice. In fact, the time required to obtain these consolidated data is around 6 months to 1 year. However, in our study, the hospital data was the only available and relevant data source. Since the middle of 2023, the surveillance system for severe cases of influenza (cases hospitalised in ICU) has been extended to bronchiolitis, and could be used to illustrate the gravity of the disease.

From a global perspective, it would be valuable for countries that have already applied the MEM approach to influenza epidemics to extend its use to bronchiolitis, enabling a worldwide assessment of epidemic intensity. The MEM approach could also serve as an effective tool for evaluating the impact of the RSV bronchiolitis prevention campaign on epidemic severity in 2023/24. In France, the human monoclonal antibody Beyfortus®

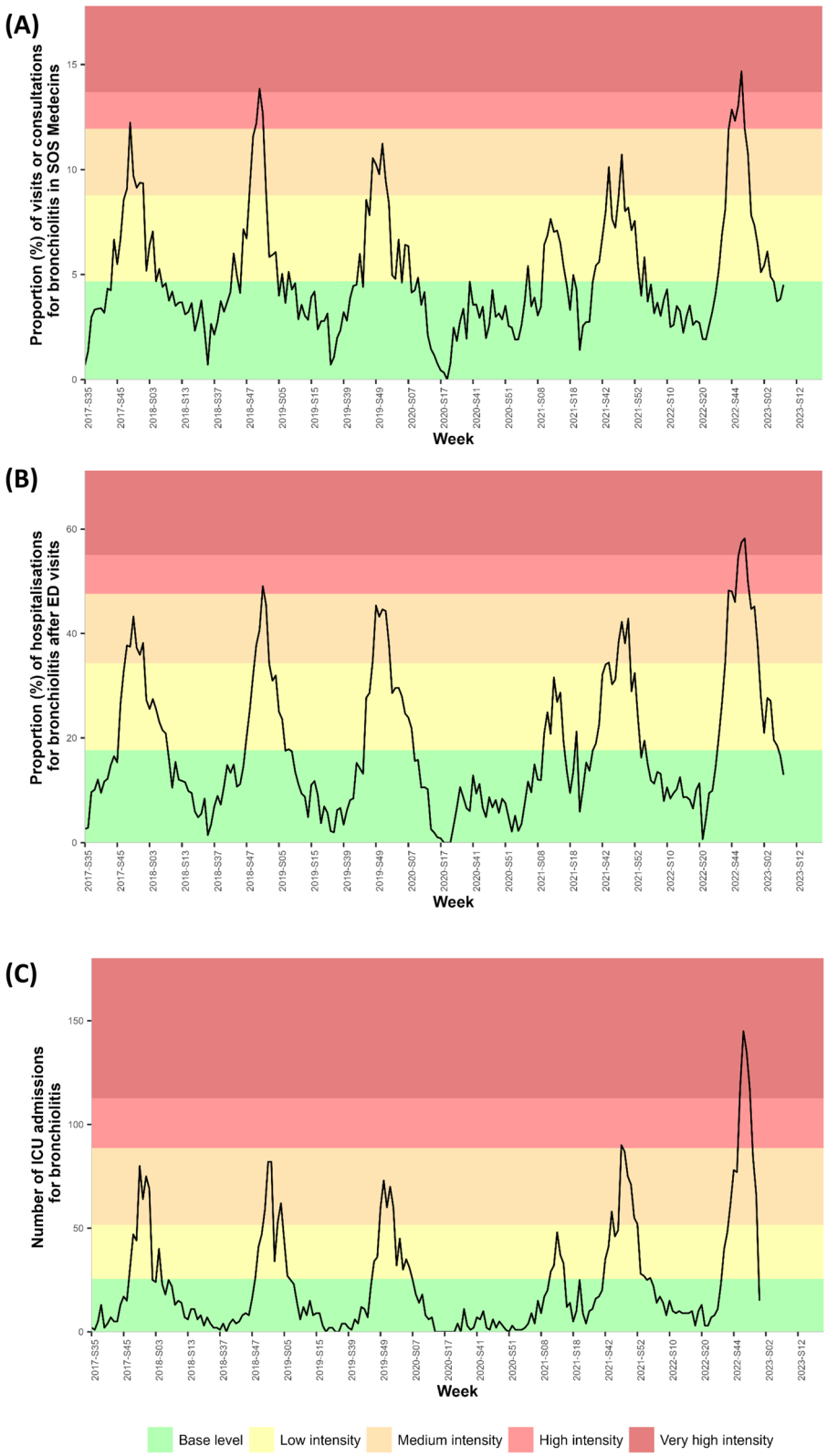


Fig. 2 Severity of the bronchiolitis epidemics for the 2017/18 to 2022/23 seasons in Nouvelle-Aquitaine, according to MEM indicators

(nirsevimab) has been available since September 2023 for the protection of infants during their first RSV season and the vaccine Abrysvo® has been available since September 2024 for the vaccination of pregnant women to protect newborns through maternal antibody transfer. Monitoring bronchiolitis severity using MEM could provide insights into the effectiveness of this immunisation strategy.

Conclusions

The MEM approach was used to assess the severity of bronchiolitis epidemics in Nouvelle-Aquitaine over the period from 2017–2023. The findings from this successful exploratory study led to the implementation of MEM in ongoing bronchiolitis surveillance in Nouvelle-Aquitaine, including incorporation of results in regional epidemiological bulletins, providing valuable public health information to support intervention strategies. It would also be beneficial for countries that have already applied MEM to influenza to extend its use to bronchiolitis, facilitating global assessment of bronchiolitis epidemic intensity.

Overall, the MEM is a simple, rapid and effective tool for informing public health decision-makers and healthcare establishments in near real-time about the severity of an ongoing epidemic, guiding the implementation of appropriate management measures, such as the activation of hospital emergency plans. Such contingency plans allow the immediate mobilisation of human and material resources in the event of an influx of patients or an exceptional health situation. It complements existing epidemic detection systems by determining intensity levels and allowing regional, national or even international comparisons.

For future seasons, the severity assessment of bronchiolitis epidemics in Nouvelle-Aquitaine will be communicated to the regional health agency and surveillance partners (SOS Medecins and OSCOUR network and hospitals).

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-22746-9.

Supplementary Material 1.

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Authors' contributions
CC: collected data, analyzed data, reviewed literature, and wrote the manuscript. PV: analyzed data and reviewed the manuscript critically. LC : reviewed the manuscript critically. LF: reviewed the manuscript critically. All authors read and approved the final manuscript.

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Data availability
Data from the SOS Medecins du Monde and OSCOUR networks are available as open source data at https://geodes.santepubliquefrance.fr/.

Declarations

Ethics approval and consent to participate
According to French law, this study did not have to obtain the approval of a national ethics committee (the French data protection authority, CNIL (Commission nationale de l'informatique et des libertés)), as it is not legally considered to be research involving human beings and relies only on the collection of anonymous data.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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