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Short Communication

Bacterial Meningitis Hospitalizations after the 2009 L'Aquila Earthquake: A Retrospective Observational Study

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Abstract

Background and Objectives: In industrialized countries, the risk of transmission of infectious diseases after a natural disaster is low but real and associated with the characteristics of the displaced population and with endemic diseases in the geographic area. A major contribution to the transmission of infectious diseases is the overcrowding that could contribute to the epidemic of acute respiratory diseases, pneumonia and meningitis. Surveillance in areas hit by natural disasters is therefore essential to understand the impact itself of the disaster on communicable diseases. This study aimed to investigate the potential impact of the 2009 L'Aquila earthquake on hospitalizations for bacterial meningitis, conducting a retrospective observational study using the Hospital Discharge Records as informational flow. **Materials and Methods:** Hospitalization rates, expressed x 100,000 people, were standardized and stratified by belonging to the seismic crater or not. The statistical significance of the time trend of the standardized rates was assessed through the Poisson regression. **Results:** In 2009, the *H. influenzae* hospitalization rate recorded in the municipalities of the crater (0.52x100,000 people, 95% CI 0.50-1.54) was more than six times greater than that recorded for the municipalities outside the crater (0.08x100,000 people, 95% CI 0.07-0.23). For *S. pneumoniae*, rates were higher in the seismic crater than in the rest of the region and in the rest of the Italian territory only in the years 2009 and 2010, when there was a peak in hospitalization rates for pneumococcus in this area of the region (1.17x100,000 people, 95% CI 0.46-2.81). Regarding *N. Meningitidis* meningitis, no peak of hospitalization in 2009 was found out. **Conclusion:** This study demonstrated that after the 2009 L'Aquila earthquake, there was a peak of hospitalization for bacterial meningitis, probably as the result of acute lower respiratory tract infections, often caused by pneumococcus or *H. influenzae*.

Key words: meningitis, trend, hospitalization, vaccine, earthquake

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Bacterial meningitis, among all infectious diseases, is one of the most relevant in public health for three main reasons:

- They have very high death rates and are characterized by present and visible sequelae in the general population, despite being rare
- They particularly affect young children
- Vaccines are available against the three main etiologic agents (*Haemophilus influenzae* b or Hib, *Streptococcus pneumoniae* or pneumococcus, *Neisseria meningitidis* or meningococcus)¹

After a natural disaster, the risk of transmission of infectious diseases, especially in industrialized countries, is low but real and associated primarily with the characteristics of the displaced population, such as immunization levels for vaccine-preventable diseases and with endemic diseases in the geographic area under consideration^{2,3}. If a disease, in fact, is not endemic in the area affected by the calamitous event, it can't cause an epidemic after the event itself⁴. A major contribution to the transmission of infectious diseases is the overcrowding, consequence of housing the population in emergency shelters⁴. It has been documented that overcrowding contributes to the epidemic of acute respiratory diseases, pneumonia, measles and meningitis after a natural disaster⁴. In particular, acute respiratory diseases, which represent an important factor of death and disability after disasters, involve pathogens such as *H. influenzae*, *S. pneumoniae* and *N. meningitidis*⁴.

Surveillance in areas hit by natural disasters is therefore essential to understand the impact itself of the disaster on communicable diseases³. Furthermore, although post-disaster surveillance systems are developed to detect cases of epidemic risk disease rapidly, the correct interpretation of this information may be hindered by the absence of basic surveillance data which could lead to misinterpretation of cases of diseases that occur endemically as an early epidemic³.

Since the 2009 earthquake hit most of the province of L'Aquila, as well as some municipalities in the provinces of Teramo and Pescara and considering the consequent overcrowding in the tent cities, the potential impact of the earthquake was investigated, conducting a retrospective observational study of the hospitalizations for bacterial meningitis in the municipalities of the seismic crater, with particular attention to the forms preventable by vaccination, comparing the data with those relating to the municipalities outside the crater and with those on a regional and national scale.

MATERIALS AND METHODS

The study was conducted using the Hospital Discharge Records (HDRs) with at least one bacterial meningitis code listed in the main or secondary diagnosis (320.x, 003.21, 013.00-013.06, 091.81, 094.2, 100.81 and 036.0) as informational flow.

According to the classification of the municipalities of the Abruzzo region suggested by the Decrees of the Delegate Commissioner^{5,6}, HDRs in the 57 municipalities belonging to the seismic crater (crater) were compared with those relating to the municipalities not related to the crater (non crater), provided by the Regional Health Agency-Abruzzo (ASR) for 2009-2015 time frame and with the regional and national data, provided by the Ministry of Health-General Management of Health Planning-Hospital Discharge Records Database.

Data analysis: The tests used were bidirectional and used with a level of significance of 5%. The data, stored electronically were processed using the statistical package STATA/IC15.0.

The study was approved by the Internal Review Board of the University of L'Aquila (No. 02/2018).

The comparison of the frequency distributions by gender, age group, etiology, type of coding and number of deaths was made between the national data and the crater and between crater and non-crater and the statistical significance was analyzed using the χ^2 test.

Hospitalization rates, expressed x100,000 people were standardized and stratified by belonging to the seismic crater or not and, for the three forms of vaccination-preventable meningitis, related to the specific national and regional vaccination coverage, derived from literature⁷⁻¹⁹, which trend was analyzed with the slope of the regression line. The statistical significance of the time trend of the standardized rates was instead assessed through the Poisson regression.

RESULTS

In the time period 2009-2015, the number of hospitalizations for bacterial meningitis in Italy was 12,833, 309 of which reported Abruzzo as the region of hospitalization: 278 in the municipalities of the seismic crater and 31 in the municipalities external to the crater. Statistically significant differences emerged regarding the distribution by age groups, with a hospitalized population in the 18-44 age group about four times higher in the municipalities outside the crater compared to those of the crater (25.54 vs. 6.45%, p-value = 0.014) and a representativeness of the class >85 years more than six times greater in the crater than the national data (12.90 vs. 1.96%, p-value = 0.003). As regards the

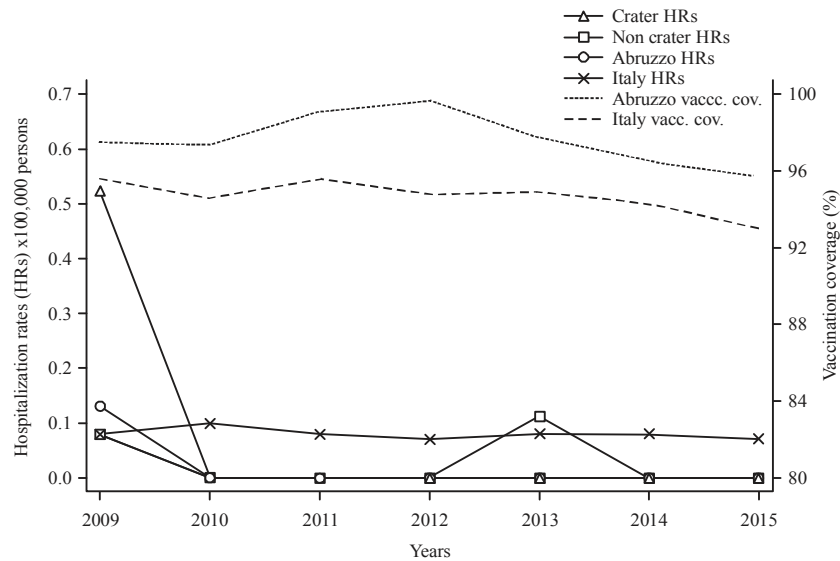


Fig. 1: Hospitalization Rates x100,000 for *H. influenzae* meningitis and anti-Hib vaccination coverage (2009-2015 time frame). Trend test. Crater: β coefficient = -0.056, p-value = 0.144, Non Crater: β coefficient = -0.165, p-value = 0.889; Abruzzo: β -coefficient = -0.014, p-value = 0.144, Italy: β -coefficient = -0.001, p-value = 0.203; Coverage for Abruzzo: β -coefficient = -0.093, p-value = 0.493, coverage for Italy: β -coefficient = -0.239; p-value = 0.004

distribution of the frequencies of the aetiologies involved, a statistically significant difference was found for the number of non-pneumoniae streptococcal hospitalizations, which in the municipalities of the crater was about twice as much as the recorded data on a national basis (22.58 vs. 8.94%, p-value = 0.018).

For each vaccine-preventable aetiology, national and regional hospitalization rates were compared also stratified by belonging or not to the seismic crater, to vaccine coverage data.

Regarding the *H. influenzae* hospitalizations (Fig. 1), a decreasing trend for both the areas of the Abruzzo region under consideration and for the national data was shown. In 2009 there was a slight decrease in vaccination coverage of 0.4 and 0.1%, respectively, at regional and national levels compared to the previous year, related to a peak of the hospitalization rates. The hospitalization rate recorded in the municipalities of the crater in that year (0.52x100,000 people, 95% CI 0.50-1.54) was instead more than six times greater than that recorded for the municipalities outside the crater (0.08x100,000 people, 95% CI 0.07-0.23), which value coincided with the national one. The drop in vaccination coverage in the Abruzzo region recorded in 2013 compared to the previous year (97.75 vs. 99.70%) was associated with an increase in the hospitalization rates for municipalities outside the earthquake crater. An interesting finding was an adherence to the anti-Hib vaccination in the Abruzzo region better than the national data, with an average vaccination coverage for

the period 2009-2015 of 97.67% against 94.69%. However, the trend of anti-Hib vaccination coverage for the years resulted to be decreasing both for the Abruzzo region (coefficient β = -0.093; p-value = 0.493) and for the entire national territory (coefficient β = -0.239; p-value = 0.004), for which the decrease was more marked and statistically significant.

As concerning *S. pneumoniae* (Fig. 2), rates were higher in the seismic crater than in the rest of the region and in the rest of the Italian territory only in the years 2009 and 2010, when there was a peak in hospitalization rates for pneumococcus in this area of the region (1.17x100,000 people, 95% CI 0.46-2.81); then it remained constantly below the national average with a decreasing trend (coefficient β = -0.322; p-value = 0.320), unlike what was recorded for the municipalities outside the crater (coefficient β = 0.066; p-value = 0.769). The trend of the anti-pneumococcal vaccine coverage resulted to be strongly increasing both at regional level (coefficient β = 15.125; p-value = 0.281) and for the national data (coefficient β = 4.347; p-value = 0.001), for which statistical significance was shown.

Regarding the rates of hospitalization for *N. meningitidis* meningitis, in the municipalities of the crater there was a single peak in 2012 (0.53x100,000 people, 95% CI 0.51-1.58) and the average hospitalization rates for the studied period (0.076x100,000 people) fell below the national (0.27x100,000 people) and regional (0.18x100,000 people) ones. The rate trend for the Abruzzo municipalities outside the

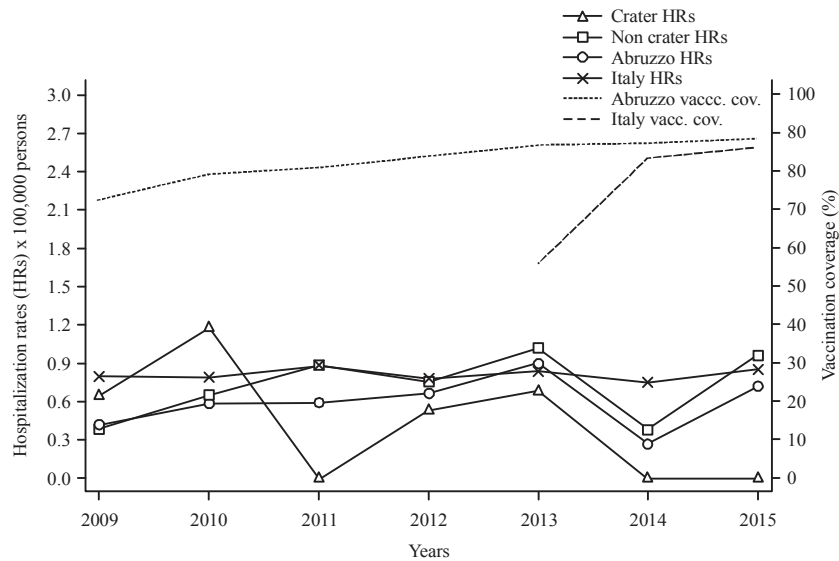


Fig. 2: Hospitalization Rates x100,000 for *S. pneumoniae* meningitis and anti-pneumococcus vaccination coverage (2009-2015 time frame). Trend test. Crater: β -coefficient = -0.322 , p-value = 0.320 , Non Crater: β coefficient = 0.066 , p-value = 0.769 ; Abruzzo: β -coefficient = 0.036 , p-value = 0.883 ; Italy: β -coefficient = -0.0007 , p-value = 0.903 ; Coverage for Abruzzo: β -coefficient = 8.296 , p-value = 0.047 , Coverage for Italy: β -coefficient = 4.347 , p-value = 0.001

crater increased, but not in a statistically significant way (coefficient $\beta = 0.017$, p-value = 0.967). The average vaccine coverage for type C meningococcus in Abruzzo was much below the national average (38.74 vs. 69.53%), but with an increasing and statistically significant trend (coefficient $\beta = 6.056$; value <0.001), similar to what emerged for the entire Italian territory (coefficient $\beta = 3.308$; p-value = 0.005).

DISCUSSION

Meningitis are among the most feared infectious diseases in the world, yet there are few population studies on the epidemiology, on the causes and on the temporal trends of these diseases, especially in industrialized countries²⁰.

This study showed low hospitalization rates for bacterial meningitis by *H. influenzae* demonstrating that the disease remained rare in Italy and as in other low-incidence countries, such as the USA, the persistence of cases of meningitis by *H. influenzae*, despite the extensive vaccination coverage achieved by anti-Hib immunization was probably linked to non-vaccinal or non-typable serotypes²¹. Considering that the coverage trend was slightly decreasing in Italy, the variations of the incidence of the disease must be carefully analyzed in order to observe a possible recrudescence.

The trend of the anti-pneumococcal vaccination coverage was increasing, bringing benefits in terms of health of the population, since it was shown that the anti-pneumococcal vaccination could give rise to indirect effects (herd immunity),

probably due to the reduction of nose-pharyngeal colonization, for which rates of incidence of reduced pneumococcal meningitis were also recorded in the non-target population for vaccination^{21,22}.

This finding was also valid for the anti-meningococcal vaccination, for which the coverage trend in Italy was increasing, although with lower percentages compared to the anti-pneumococcal vaccination.

Among the environmental factors that could promote the air transmission of infectious diseases, the overcrowded environments, in addition to poor ventilation and intimate contact were reported²³.

After the earthquake that occurred in 2009 in L'Aquila, which caused 309 deaths, 1,600 injured and 70,000 displaced people, as a first solution the residents of the crater municipalities were partly welcomed to the tent camps set up in emergency and partly in hotels on the coast; these accommodation solutions were subsequently replaced by the CASE Project and the MAPs²⁴⁻²⁶. It was therefore investigated whether the housing of the population in the tent camps could have eased the transmission of meningeal infections among the displaced. It emerged that in 2009, in the municipalities belonging to the seismic crater, the hospitalization rates for meningitis from *H. influenzae* and *S. pneumoniae* were, respectively, about 5 and 2 times higher than the values recorded in the other municipalities of the Abruzzo region and in the national territory. Unlike what was found in several studies about the onset of infectious diseases after a natural disaster, for meningococcal meningitis

there were no higher hospitalization rates in 2009. This was probably due to the fact that, although this disease was easily transmitted from person to person in situations of overcrowding and cohabitation in close contact with infected subjects, its spread also depended on other risk factors such as poor hygiene and limited access to medical care, which might occur more frequently in non-industrialized countries. For example, meningitis outbreaks have been documented since the 2004 tsunami in Indonesia and since the 2005 Pakistan earthquake²⁷.

In the case of L'Aquila, however, the high rates of hospitalization found could be the result of acute lower respiratory tract infections, often caused by pneumococcus or *H. influenzae*, almost always of type B, as well as occasionally by *Staphylococcus aureus* or other streptococci: in fact, acute respiratory infections were counted among the main causes of illness and death in displaced populations^{3,28,29}.

This study had several limitations. The use of hospital discharge records (HDRs) as a source of information on cases of bacterial meningitis, considering only the hospitalized cases, could lead to an underestimation of cases of illness. Moreover, the HDRs were prone to errors of diagnosis and categorization and did not allow discrimination between community and nosocomial infections³⁰. However, because the study was the first to be conducted on a national scale, it was able to clearly describe the burden of the disease in Italy³¹.

Bacterial meningitis were the only object of this analysis, but this could also be a limit because the phenomenon of the replacement of serotypes could lead to a reduction of meningitis, yet accompanied by increased rates of otitis, bacteraemia or other infections. However, in the case of pneumococcus, for instance, there was a general downward trend of pneumococcal otitis media, pneumonia and invasive diseases, indicating an overall reduction in the burden of these bacterial infections after the advent of the 13-valent³²; instead there were few data on the surveillance of infectious diseases following the earthquake³³.

Lastly, the lack of information on serotypes represented a great limit to this investigation.

CONCLUSION

The potential impact of the 2009 L'Aquila earthquake on the health of the population had been investigated mainly from a psychological point of view until now. This analysis supplied the data related to the hospitalizations for bacterial meningitis in the municipalities related to the seismic crater, highlighting a peak in admissions for meningitis by *H. influenzae* or pneumococcus, probably linked, in turn, to an increase of infections of the upper and lower respiratory tract.

SIGNIFICANCE STATEMENT

This project was born from the collaboration between the University of L'Aquila and the Regional Healthcare Agency (Abruzzo) in order to assess the health effects of the earthquake that struck the Abruzzo region in 2009 with the aim of greater preparation of health services and better prevention of adverse effects. Our study demonstrated that after the 2009 L'Aquila earthquake, there was a peak of hospitalizations for bacterial meningitis, probably as the result of acute lower respiratory tract infections, often caused by pneumococcus or *H. influenzae*.

There is few information about the risk of transmission of infectious diseases after a natural disaster in industrialized countries. The present study helps to overcome this gap, confirming the importance of surveillance for the implementation of control strategies and of prevention of bacterial meningitis in relation to a seismic event.

Bacterial meningitis, among all infectious diseases, is one of the most relevant in public health. This study helps to deepen the knowledge about the epidemiology of meningitis in Italy, especially after a natural disaster.

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