Health & Place 47 (2017) 115–125

Contents lists available at ScienceDirect

Health & Place

journal homepage: www.elsevier.com/locate/healthplace

Deep coal mining and meningococcal meningitis in England and Wales, 1931–38: Ecological study, with implications for deep shaft mining activities worldwide

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ARTICLE INFO

Keywords:
Deep coal mining
Ecological study
England and Wales
Meningococcal meningitis
Regression analysis

ABSTRACT

The hypothesized role of deep coal mining in the development of community-based outbreaks of meningococcal meningitis has gone largely unexplored. Taking the coalfields of Britain as a historical testbed, techniques of linear and binomial logistic regression were used to assess the association between meningococcal meningitis rates and male occupation rates for coal mining in England and Wales during the national epidemic of 1931–32 and in its aftermath. Adjusting for the epidemiological effects of age, residential density, recent changes in the number of families, housing stock and low social class, the analysis yielded evidence of a significant and positive association between coal mining occupation rates and notified levels of meningitis activity in the epidemic period. Communities in areas of the world that currently maintain substantial deep coal extraction industries may be at increased risk for the epidemic transmission of meningococcal meningitis.

1. Introduction

Invasive meningococcal disease represents a major global health challenge (Nadel, 2012; Jafri et al., 2013; Sridhar et al., 2015). Worldwide, an estimated 500,000 cases occur annually (Nadel, 2012), with meningococcal and other forms of meningitis ranking among the most important infectious and parasitic causes of ill-health, disability and premature mortality (Murray and Lopez, 2013). Prior to the advent of effective antibiotic therapies, the case-fatality rate for meningococcal disease exceeded 50%; with early diagnosis, modern therapies and supportive measures, the case-fatality rate is of the order of 5–15% (Heymann, 2015).

Although there is circumstantial evidence for an association between deep coal mining activities and the epidemic transmission of invasive meningococcal disease (Jehle, 1906a, 1906b; Fowler, 1907; Fraser and Comrie, 1907; Patrick and Mix, 1907; Seligmann, 1926), systematic studies of the putative association have yet to be undertaken. In this paper, we address the issue by using a large historical data set of notified cases of meningococcal meningitis in England and Wales in the period 1931–38. The population of England and Wales experienced three pronounced epidemics of the disease in the first half of the twentieth century (Fig. 1) (Reece, 1916; Underwood, 1933, 1940). While the epidemics of 1915–18 (World War I) and 1940–42 (World War II) are deemed to have been linked to military mobilisation and the population upheavals of wartime Britain (Smallman-Raynor and Cliff, 2012), the factors associated with the development of the intervening epidemic of 1931–32 remain largely unexplored. As *The British Medical Journal* noted in 1940,

> When the recorded history of this disease is examined its predilection for soldiers is apparent, and the like sequence to mobilization of our two major epidemics in 1915 and 1940 is notable. Nevertheless, the first severe outbreak in this country – which occurred in Glasgow, the West of Scotland, and Northern Ireland in 1906–7 – had no such connexion, nor had the North of England outbreaks of 1931–2, which caused the national notification figures to rise nearly as high as in 1915 (Anonymous, 1940, p. 776).

Humans are the reservoir of the bacterial agent of invasive meningococcal disease (*Neisseria meningitidis*) and exposure to respiratory droplets from the nose and throat of a carrier is the primary route of transmission (Heymann, 2015). The majority of infections are asymptomatic; invasive disease is seen in less than 1% of those colonized. Young people (infants, adolescents and young adults) are particularly prone to the development of meningococcal disease, and factors such as population mixing and crowding, low socioeconomic status, exposure to tobacco smoke and concurrent upper respiratory

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http://dx.doi.org/10.1016/j.healthplace.2017.08.002
Received 19 July 2016; Received in revised form 3 August 2017; Accepted 4 August 2017
Available online 13 August 2017
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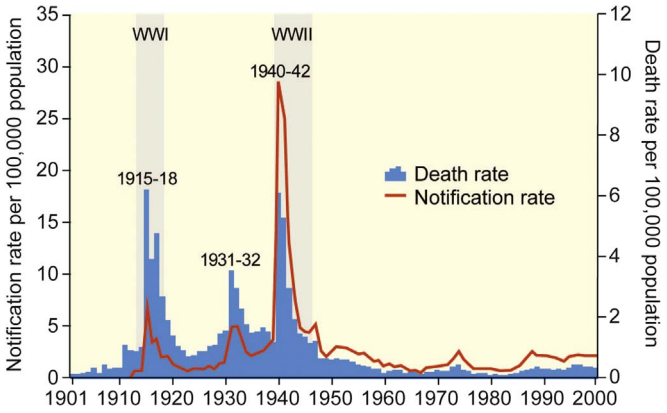

Fig. 1. Time series of meningococcal disease in England and Wales, 1901–2000. Annual death rate (1901–2000; bar chart) and notification rate (1912–2000; line trace) per 100,000 population. The principal epidemic phases (1915–18, 1931–32 and 1940–42) are indicated.
Source: data from Registrar-General for England and Wales (1923), Central Statistical Office/Office for National Statistics (1974–2002) and Mortality Statistics Unit (2003).

tract infections are associated with a heightened risk of the disease. Specific risk groups include military recruits, Hajj pilgrims, people with compromised immune systems and travellers to geographical areas where the disease is epidemic (Heymann, 2015). Consistent with this evidence, Underwood (1933) attributed the distinctive geography of the 1931–32 epidemic in England and Wales (Fig. 2A) to the demographic structure of certain affected localities and, in particular, to the heightened transmission risk associated with the massing of large numbers of young and susceptible families in Britain's inter-war housing estates (Lloyd George's 'homes fit for heroes').

The deep coal mining industry – which accounted for almost 7% of the male workforce of England and Wales at the time of the 1931–32 epidemic – is one industrial-occupational factor that may have shaped the spatial patterns of disease activity in Fig. 2A. The documented links between deep coal mining and meningococcal meningitis can be traced to Simon Flexner's classic investigation of a severe outbreak of the disease in the small mining town of Lonaconing, Maryland, in 1893 (Flexner and Barker, 1894). But it is the little-known German-language studies of Dr Ludwig Jehle, a Czech-born paediatrician, that are of special epidemiological interest. Drawing on evidence from mining communities in the vicinities of Orlau (Silesia, Czech Republic) and Duisburg (Ruhr, Germany) during the epidemics of 1905–6 in continental Europe, Jehle demonstrated that cases of meningococcal meningitis were concentrated among children whose only links were via fathers who were employed in particular coal mines and particular mine shafts (Jehle, 1906a, 1906b). Informed by Jehle's observations, Seligmann's (1926) study of meningococcal meningitis in Prussia, undertaken on behalf of the Health Organisation of the League of Nations, identified a "remarkably high" number of cases of the disease in the households of underground coal miners (p. 12) and that the disease demonstrated "a distinct preference for mining districts" (p. 22). According to Seligmann,

> There is no doubt … that the conditions obtaining in coal-mines are favourable to the spread of the disease. Two factors have been adduced in explanation of this remarkable fact. In the first place, the atmospheric conditions in the mines, which, according to Jehle, constitute what might be described as a "vast natural incubator" on account of the moist heat and darkness. In mines, meningococci, which elsewhere have very feeble powers of resistance, can survive for some days even outside the human organism. The conditions in mines are also favourable to direct personal contagion. This mode of

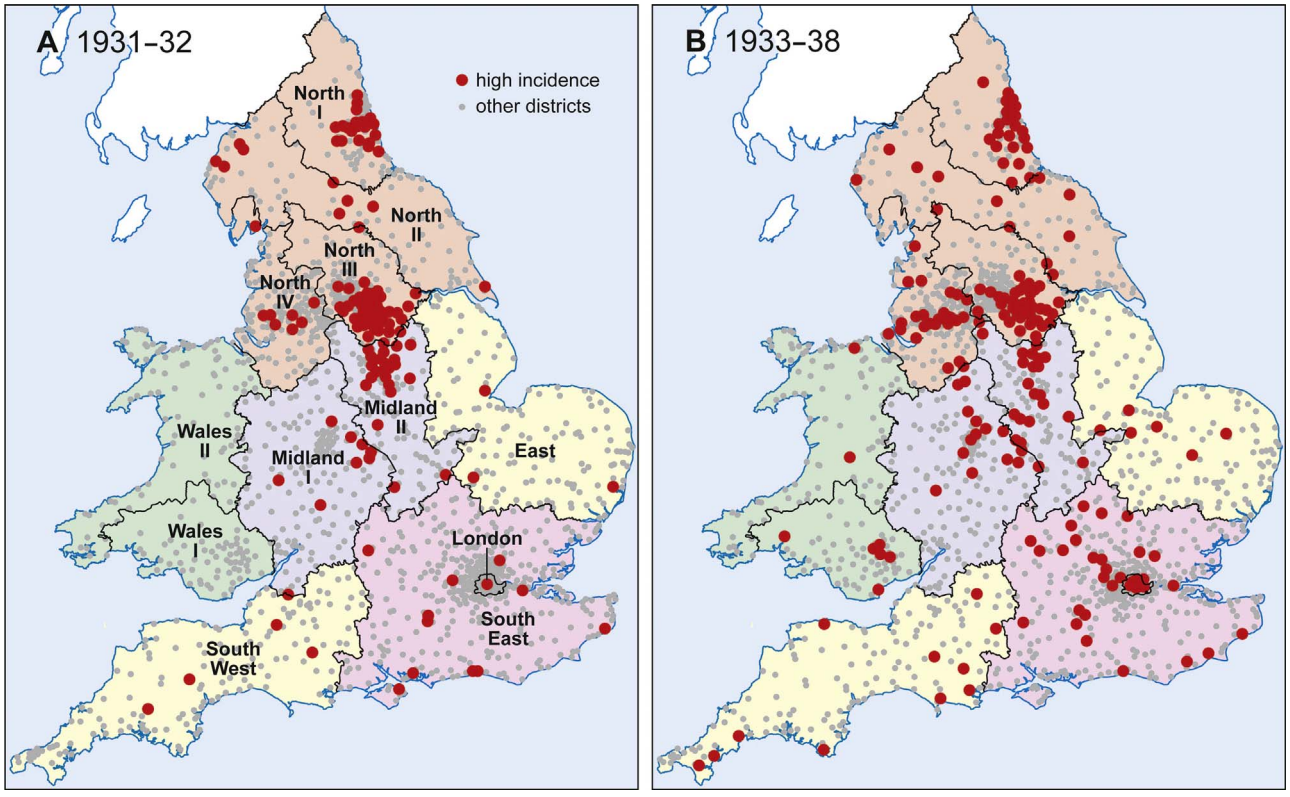

Fig. 2. Local government areas of England and Wales with high notification rates for meningococcal meningitis, 1931–38. The maps plot, as large circles, those areas with elevated meningitis notification rates per 100,000 population in the epidemic (1931–32) and post-epidemic (1933–38) periods. Elevated notification rates are defined according to the upper quartile (Q3) of the distribution of non-zero meningitis rates in each time period. All other local government areas are represented by grey dots. The boundaries of the Registrar-General's contemporary classification of regions and subregions are marked on each map; subregions are named.
Source: data from Registrar-General for England and Wales (1923) and Census Office (1934).