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Variola minor in coalfield areas of England and Wales, 1921–34: Geographical determinants of a national smallpox epidemic that spread out of effective control

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ABSTRACT

This paper uses techniques of binary logistic regression to identify the spatial determinants of the last national epidemic of smallpox to spread in England and Wales, the variola minor epidemic of 1921–34. Adjusting for age and county-level variations in vaccination coverage in infancy, the analysis identifies a dose-response gradient with increasing odds of elevated smallpox rates in local government areas with (i) medium (odds ratio [*OR*] = 5.32, 95% Confidence Interval [95% CI] 1.96–14.41) and high (*OR* = 11.32, 95% CI 4.20–31.59) coal mining occupation rates and (ii) medium (*OR* = 16.74, 95% CI 2.24–125.21) and high (*OR* = 63.43, 95% CI 7.82–497.21) levels of residential density. The results imply that the spatial transmission of variola virus was facilitated by the close spatial packing of individuals, with a heightened transmission risk in coal mining areas of the country. A syndemic interaction between common respiratory conditions arising from exposure to coal dust and smallpox virus transmission is postulated to have contributed to the findings. We suggest that further studies of the geographical intersection of coal mining and acute infections that are transmitted via respiratory secretions are warranted.

1. Introduction

The global eradication of smallpox was one of the remarkable achievements of twentieth-century public health medicine (Fenner et al., 1988). In October 1977, after an intensified 10-year campaign against the disease, the World Health Organization (WHO) traced the last naturally occurring case of smallpox to the town of Merca in southern Somalia. Two years later, with no further cases of the disease (barring laboratory incidents) having been recorded, the WHO formally announced that the global eradication of smallpox was complete (Fenner et al., 1988). Today, authorised holdings of smallpox (variola) virus are maintained for research purposes in laboratories in Atlanta (USA) and Siberia (Russia). The fate of these remaining virus stocks is due to be decided at the Seventieth World Health Assembly in May 2017 (Arita and Francis, 2014).

The advent of a peculiarly mild form of smallpox – known as variola minor – represents one of the more enigmatic episodes in the modern history of the disease (Fenner et al., 1988, pp. 315–63). Variola minor was first recognised in the latter part of the 1890s, and it was this mild form of the disease that presented particular challenges to the WHO's global eradication programme as smallpox was pushed back to the Horn of Africa in the 1970s (Fenner et al., 1988, p. 326). Few explicitly geographical studies of large-scale epidemics of the disease have been published, and the geographical determinants and drivers of variola minor in specific epidemic settings – such as inter-war England and Wales – are largely unknown (Angulo et al., 1977; Fenner et al., 1988; Splaine et al., 1974; Stocks, 1933a, b).

This paper uses small-area data for a protracted epidemic of variola minor that spread in England and Wales in the 1920s and 1930s to analyse the spread mechanisms behind the epidemic. This epidemic marked the last occurrence of smallpox as an endemically-transmitted infection in the British Isles (Fenner et al., 1988, pp. 324–6; Smallman-Raynor and Cliff, 2012), and is a prime example of a geographically extensive smallpox epidemic that diffused in an uncontrolled manner in a national population with waning levels of vaccine-induced immunity (Ministry of Health, 1921, 1922–45). Adopting a retrospective cross-sectional design that encompasses the complete records of notified smallpox

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activity in 1874 local government areas of England and Wales, 1921–34, our analysis demonstrates that the spread of variola minor was strongly related to spatially-localised population proximity. Close spatial packing of individuals facilitated variola virus transmission via direct contact of susceptibles with the oropharyngeal secretions of infectives, with a heightened transmission risk in coal mining areas of the country. A syndemic interaction between common respiratory conditions arising from exposure to coal dust (catarrh, chronic rhinitis, pharyngitis) and the primary transmission route of variola virus (exposure to oropharyngeal secretions) is postulated to have contributed to the spatial associations we report. This postulated interaction has implications for the investigation of coal mining in relation to a range of other acute infections that are transmitted via respiratory secretions, including diphtheria, measles, meningococcal meningitis and streptococcal diseases.

2. Background: variola virus and the 1921–34 smallpox epidemic in England and Wales

2.1. Nature of smallpox

Smallpox was an acute infectious disease caused by variants of variola virus. Humans were the only reservoir of variola virus and the primary routes of smallpox transmission were through direct contact with the oropharyngeal secretions of an infected person and, less commonly, via contact with contaminated objects (fomites) such as the clothing and bedding of patients (Fenner et al., 1988; Heymann, 2015). As described by Heymann (2015, pp. 561–4), a typical incubation period of 10–14 days (range: 7–19 days) gave way to a non-specific prodromal illness that was characterised by the sudden onset of fever, headache, malaise and prostration. After 2–4 days, a characteristic rash appeared on the face and other parts of the body that pustulated and scabbed after 3–4 weeks. The period of infectivity of a patient extended from the first appearance of skin lesions to the disappearance of virus-harbouring scabs.

2.1.1. Clinical types and severity

Studies of the evolutionary history of variola virus suggest that twentieth century lineages of the virus had been in existence for ~200 years, and that they had evolved in tandem with extant processes of globalisation and vaccine control (Duggan et al., 2016). These lineages were associated with two recognised clinical forms of the disease: *variola major* and *variola minor* (Heymann, 2015, pp. 561–4). Variola major was the more severe form of the disease; historically, it was associated with a high case-fatality rate (~30 percent in unvaccinated populations) and, for survivors, its sequelae included severe scarring, blindness and male infertility. Variola minor, on the other hand, was a distinctly milder form of the infection (case-fatality rate <1 percent) that had first come to notice in South Africa and the United States in the late nineteenth century, and which became established in some countries of the Americas, Europe and the Pacific in the early decades of the twentieth century (Fenner et al., 1988, pp. 243–3).

2.2. The 1921–34 variola minor epidemic in England and Wales

In the United Kingdom, the Vaccination Acts of 1898 and 1907 had relaxed the mid-nineteenth laws on the compulsory vaccination of infants so that, by 1921, some 2.5 million or more children aged <12 years were legally exempted from vaccination in England and Wales (Ministry of Health, 1921). It was at about this time that variola minor began to establish itself as an epidemic of national proportions. From early foci in central and northeastern England in the early 1920s, the ensuing epidemic developed to a peak in 1927 when over 14,000 cases were notified (Fig. 1). By the termination of the epidemic in 1934, a cumulative total of 81,495 cases (including 209 deaths) had been notified from 868 local government areas (Fig. 2A).

Although the variola minor epidemic of 1921–34 was one of the outstanding epidemiological events in inter-war England and Wales (Ministry of Health, 1922–45), very little is known of the factors that shaped the geography of the disease (Rafferty, 2016; Smallman-Raynor and Cliff, 2012). Yet, underlying the broad geographical sweep of the epidemic (Fig. 2A) were pronounced groupings of high incidence areas (Fig. 2B) that lend the epidemic a distinctive spatial character. While local-area investigations pointed to the role of certain demographic (young age) and socio-economic (residential density) factors as determinants of disease activity (Stocks, 1933a, b), the extent to which these and other factors shaped the national disease pattern in Fig. 2 has yet to be determined.

2.2.1. The coal mining connection

Elsewhere, we have examined how the living and working conditions in communities attached to the coal mining industry – which accounted for some 7 percent of the male workforce of inter-war England and Wales (Fig. 3) – conditioned the epidemic spread of one acute infectious disease (meningococcal meningitis) in the 1930s (Smallman-Raynor and Cliff, 2017). In the present paper, we examine the extent to which the same mining communities conditioned the epidemic spread of smallpox in the 1920s and 1930s (Fig. 2). Our investigation is informed by incidental press coverage of the involvement of colliery towns and villages and colliers and their families in the course of the 1921–34 epidemic (Anonymous, 1923, 1924, 1926, 1927a, 1928), and by concerns expressed by senior government advisors over the possible impact of the great industrial dispute of 1926 on efforts to assert effective disease control in coalfield areas (Chief Medical Officer, 1927).

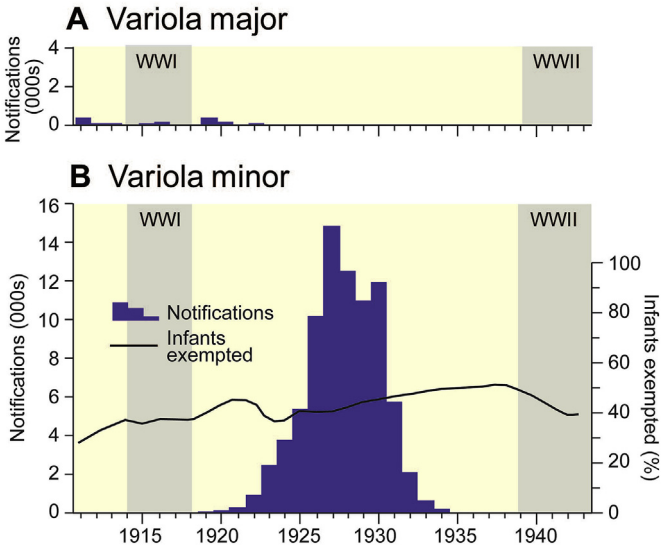

Fig. 1. Smallpox notifications in England and Wales, 1911–44. The graphs plot the annual time series of notifications of (A) variola major and (B) variola minor. The line trace in graph (B) plots, by year of birth registration, the percentage proportion of infants who were exempted from vaccination under the Vaccination Acts. Sources: data from Fenner et al. (1988, Table 8.4, p. 325), Local Government Board (1919, Appendix I, p. 207) and Ministry of Health (1922–45).