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Potential role of head lice, *Pediculus humanus capitis*, as vectors of *Rickettsia prowazekii*

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Abstract Since the pioneering work of Charles Nicolle in 1909 [see Gross (1996) Proc Natl Acad Sci USA 93:10539–10540] most medical officers and scientists have assumed that body lice are the sole vectors of *Rickettsia prowazekii*, the aetiological agent of louse-borne epidemic typhus (LBET). Here we review the evidence for the axiom that head lice are not involved in epidemics of LBET. Laboratory experiments demonstrate the ability of head lice to transmit *R. prowazekii*, but evidence for this in the field has not been reported. However, the assumption that head lice do not transmit *R. prowazekii* has meant that head lice have not been examined for *R. prowazekii* during epidemics of LBET. The strong association between obvious (high) infestations of body lice and LBET has contributed to this perception, but this association does not preclude head lice as vectors of *R. prowazekii*. Indeed, where the prevalence and intensity of body louse infections may be high (e.g. during epidemics of LBET), the prevalence and intensity of head louse infestations is generally high as well. This review of the epidemiology of head louse and body louse infestations, and of LBET, indicates that head lice are potential vectors of *R. prowazekii* in the field. Simple observations in the field would reveal whether or not head lice are natural vectors of this major human pathogen.

Introduction

For now the plague fell upon the Athenians and devoured the flower of their manhood and strength. It afflicted them not only in body but also in spirit, so they raved against Pericles and tried to ruin him, just as a man in a fit of delirium will attack his physician or his father (Plutarch 1960).

Although louse-borne epidemic typhus (LBET) was suspected as the cause of the plague that beset the Athenians, the first major epidemic that can be confidently attributed to this disease occurred in the 15th century (Perine et al. 1992). LBET, which is caused by infection with *Rickettsia prowazekii*, is one of the most devastating illnesses to afflict human kind. The word “typhus” originates from the Greek word “typhos” meaning smoke, cloud, or stupor arising from fever; it describes one of the classic symptoms of LBET. In undernourished populations, who already suffer poor health and hygiene, LBET can cause substantial mortality rates (Weiss 1998). Most medical workers and scientists consider the body louse (*Pediculus humanus humanus*) to be the only vector of *R. prowazekii*, yet there is strong experimental evidence that head lice (*P. h. capitis*) can be competent vectors of *R. prowazekii* as well (Goldberger and Anderson 1912; Murray and Torrey 1975).

Evidence that head lice can transmit *R. prowazekii*

In 1909, Charles Nicolle infected a chimpanzee with *R. prowazekii*, and then placed body lice onto it. After the lice had fed, he transferred them to another chimpanzee, which subsequently developed typhus (Gross 1996). Subsequent similar experiments with head lice gave the same result. Goldberger and Anderson (1912) took hair that contained head lice from patients who were admitted to hospital with LBET, and used these

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lice to infect rhesus monkeys with *R. prowazekii*. Their findings were later confirmed by Murray and Torrey (1975), who infected head lice with *R. prowazekii* by feeding these lice on a rabbit that was infected with *R. prowazekii*. Murray and Torrey (1975), using labelled antibodies to *R. prowazekii*, found that from the sixth day after exposure, head lice passed infective rickettsiae in their faeces. No other experiments have been reported to contradict these results.

If head lice are competent vectors of *R. prowazekii* in the laboratory why don't these lice transmit *R. prowazekii* in the field?

Maunder (1983) proposed two arguments to account for the apparent observation that infestations of body lice, not head lice, lead to epidemics of LBET. First, Maunder argued that the faeces of body lice are more likely to build up in clothes than in the hair, to levels where infection of people with *R. prowazekii* is likely. However, small amounts of faeces can be infective (Buxton 1947), and the faeces of head lice may build up to substantial levels on the scalp, hair and on pillows of infested people (Burgess 1995). Moreover, the dust-like faeces of *P. humanus* in the hair are perfectly placed for infection via inhalation, scratches of the scalp or the conjunctiva and mucosal membranes. Indeed, the faeces may be so infective that hospital cleaners in Russia who had no direct contact with patients became infected when washing the linen of typhus patients (Patterson 1993), presumably through inhaling louse faeces that became airborne while they were handling the linen.

Second, Maunder (1983) argued that since body lice are present in larger numbers than head lice during epidemics of LBET, body lice are the principal or sole vectors of *R. prowazekii*. However, there is evidence that head lice are also present in large numbers during epidemics of LBET. For example, in the 1975 outbreak of LBET in Uganda, nits were found in both the hair and clothes of patients, confirming the presence of head lice, but the proportion of head and body lice was not measured (Banegura et al. 1983). Between 1981 and 1990, Ethiopian refugee camps accounted for 69% of all reported cases of epidemic typhus (Perine et al. 1992). Head lice were found on 65% of these people, and close to 100% of children, whereas only 30% of these people had body lice (Raoult and Roux 1999). Presumably, head lice can be present in equally large numbers during epidemics of typhus. The fact that head lice are prevalent in many if not all human societies that have never had LBET reinforces the perception that head lice do not transmit *R. prowazekii*. But, of course, this observation does not exclude head lice as vectors of *R. prowazekii* during epidemics of LBET, since the conditions that lead to prevalent and intense infestations of *P. h. humanus*, such as crowding, usually lead to prevalent and intense infestations of *P. h. capitis* too.

There is insufficient evidence to decide whether head lice: (1) transmit *R. prowazekii* in the field; or (2) have an important role in epidemics of LBET. Certainly, head lice have the potential to be vectors of *R. prowazekii* in the field. Moreover, the delousing procedures that have been used in the past, and the almost universal assumption that only body lice transmit *R. prowazekii*, may have masked the role of head lice in epidemics of LBET. Head lice are generally ignored in investigations of typhus outbreaks. Despite this, patients are often, perhaps always, treated for head lice. The Russian army sterilized clothes and bedding, then washed and shaved people's heads to bring epidemics of LBET under control (Patterson 1993). So it cannot be concluded that body lice were the only vectors present in these epidemics, since head lice were also eliminated. In the aftermath of World War I an outbreak of LBET occurred which threatened to cause significant loss of life. The American army responded with an extensive campaign to control epidemic typhus in Poland between 1919 and 1920 (Foster 1981). Although the aim was to eliminate body lice, by providing clean clothing and blankets, the people's heads were also shaved. The 1975 outbreak of LBET in Uganda where patients were found with nits in their clothing and hair led to a comprehensive campaign of delousing and treatment with tetracycline (Banegura et al. 1983). By destroying the rickettsiae in the host, the bacteria could not be transmitted by any head or body lice that survived delousing. An outbreak of LBET in a Burundi jail in 1996, attributed to the presence of body lice, was contained with delousing procedures that included head-shaving (Bise and Coninx 1997; Raoult et al. 1997). While the investigators were unsure if head lice were involved in the epidemic, they treated patients for head lice just in case. Thus, the role of head lice in transmission of *R. prowazekii* during epidemics of LBET cannot be determined since both head lice and body lice were eliminated.

Clearly head lice have generally been overlooked in studies of typhus outbreaks. Even in the unusual cases when typhus sufferers are examined for head lice, these lice are then not tested for the presence of *R. prowazekii*. For example, during the 1997 outbreak in Lipetsk, Russia, body louse infestations were described as ubiquitous (Tarasevich et al. 1998). However, no mention was made about the presence of head lice, or whether the delousing measures used to control the outbreak included head-shaving. During a 1997 field study in Burundi, 102 refugees with febrile illness were examined to determine the prevalence of typhus within the population (Raoult et al. 1998). Serum was collected and body lice were removed, but once again head lice were not collected, or examined. In a Peruvian study, (Raoult et al. 1999), again body lice were collected and tested for *R. prowazekii*, but not head lice. An interesting case occurred in 1998, when a man returning from Algeria to France developed louse-borne typhus (Niang et al. 1999). No evidence of body lice was found but he did

recall having pruritus of the scalp and scratching during his stay in Algeria (Niang et al. 1999).

If head lice do transmit *R. prowazekii* to people, why have there not been outbreaks of LBET in the schools, homes and institutions of developed countries where these parasites are prevalent? The first requirement is that the aetiological agent of LBET, *R. prowazekii*, must be present. Further, people generally have to be stressed or immuno-compromised from latent infections of *R. prowazekii* to suffer patent infections of LBET (i.e. Brill-Zinsser disease) (Patterson 1993; Raoult and Roux 1999).

Conclusions

Clearly, body lice have played a role in all epidemics of LBET investigated so far, but this does not preclude head lice as additional vectors of *R. prowazekii*. This question will be answered only when head lice are collected during outbreaks of LBET and examined for *R. prowazekii*. Head lice from typhus patients should be examined for *R. prowazekii*. However, we note infection with *R. prowazekii* has often killed researchers, doctors, nurses and even laundry workers who have only had contact with faeces from patients sheets. Care is essential!

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