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The Louse in Relation to Typhus Fever, by MELVILLE D. MACKENZIE, M.D., D.P.H.,
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(Read at a Sessional Meeting in London, June 3rd, 1942.)

BEFORE proceeding to outline some of the facts now known about the relationship of the human louse to typhus, it is fitting that we should recall the patient work and the number of deaths among laboratory workers and clinicians which have been necessitated in collecting the knowledge we now use from day to day in the control of a typhus epidemic. The louse can only be kept alive by regular feeds of human blood, the disease has a mortality of 30 per cent. to 70 per cent. amongst young adults, and there is no protective vaccine of known efficacy against epidemic typhus. These three facts alone enable us to realize the debt owed to research workers in this disease, particularly if we recollect the terrible scourge that was typhus until the carrier of the disease was discovered. To me, as to medical officers the world over in typhus regions, has fallen the interest of interpreting in terms of the control of epidemic typhus under very varying conditions in the field the facts that have been put at the disposal of administrators by laboratory workers, entomologists and clinicians. In preparing this paper I have attempted to set out the generally accepted facts about the relationship between the louse and typhus fever and to show how these are utilized by those whose responsibility it is to check epidemic typhus. A glance at the incidence figures of deaths in Great Britain one hundred years ago, and the fact that the disease, except for accidental introductions, is now unknown in this country, demonstrates dramatically the value of the application of our knowledge.

Nevertheless, widespread epidemics still occur. In Russia during the period 1919-22 the estimated number of cases was ten millions, with three million deaths, in a population of one hundred and twenty millions, in addition to the extensive epidemics which existed simultaneously in Bulgaria, Poland, Roumania, and Yugoslavia. The fact that the disease still kills millions in the widespread epidemics that follow wars is due only to the difficulties in the field of applying the measures which we know will control the disease. Famine conditions increasing the mortality rate, overcrowding, a destitute and illiterate louse-infested population, transport difficulties, absence of local administrative machinery of any kind, the presence of other diseases, such as relapsing fever and malaria in epidemic form, shortage of medical men and hospital accommodation are all factors accompanying typhus epidemics, over which we may have little control.

From what has been said—and I think this is a point which should be emphasized, as it is one upon which there appears to be some confusion—an outbreak of typhus in Britain with its network of efficient health authorities, reasonable housing, and properly nourished population is an entirely different problem to such widespread epidemics abroad as have made this disease notorious. In this country it is possible to apply our knowledge—isolate a patient, supervise the contacts and kill the great majority of the lice that may be carriers—so that the outbreak would under normal conditions be ringed round, if not when the first case appeared, at any rate on the appearance of secondary cases. Elsewhere it may be very different, and in discussing typhus it is essential to bear these two aspects constantly in mind. Obviously, in the event of a military catastrophe, it is possible that the conditions for the spread of typhus on an epidemic scale in this country might be created.

The organism causing louse-borne typhus fever is one of the organisms of the *Rickettsia* group, known as the *Rickettsia prowazekii*.

There are several diseases due to other members of the *Rickettsia* group, but we are concerned immediately only with epidemic typhus, which is carried solely by the human louse. Louse-borne typhus fever is the only form of *Rickettsial* infection that occurs in epidemic form, and consequently the only one of public health interest. In all other *Rickettsial* infections—Rocky Mountain fever, Japanese river fever, murine typhus, etc.—we have a disease primarily of domestic animals or of small rodents, only occasionally and accidentally conveyed to man; whilst in the case of louse-borne typhus we have an illness conveyed directly from man to man by a parasite. It is, however, of interest to note that there is evidence that mild murine typhus, which occurs in rats and which is normally carried from rat to rat by the flea,

experimentally transmitted to man by the louse, may develop the fulminating character of true louse-borne typhus fever.

There are, as you are aware, three varieties of human louse—the head louse, the body louse, and the pubic louse. The last is not recognized as a carrier of typhus, probably not so much owing to its inability to carry the disease, but rather to the fact that it lives on parts that are kept covered, and consequently is not so easily transferred mechanically to another person. In addition, during its lifetime it moves very little, if at all, from the immediate locality in which it was born. The head louse and body louse are, in the great majority of cases, indistinguishable. Whilst it is true that a typical head louse has a different form to a typical body louse, the great majority of insects are indistinguishable one from another. Moreover, head and body lice bred together not only produce offspring, but these offspring are fertile. The body louse is therefore ordinarily considered only to be a special form of the head louse which has changed its habits as man began to wear clothing and his body hair disappeared. The head louse tends to live on the head and to lay its eggs in the hair, whilst the body louse lives generally on the body and lays its eggs mostly in the underclothing. Consequently, the head louse is not nearly so mobile as the body louse, which is easily brushed off by a passer-by or is shed in dressing and undressing. Administratively we must consequently regard both the head and body louse as possible vectors of typhus fever.

The eggs of the human louse hatch about nine days after having been laid, and the louse takes a further nine to ten days to reach maturity. The adult female lives about a month and lays eight to ten eggs a day, so that the total is in the region of three hundred. Lice only live for about a week off the body and without food, but their eggs may hatch out over a period of about three weeks.

It is not, however, only with the life history of the insect that we are concerned in the control of typhus but also with its habits and inclinations.

Lice, provided they are warm and have food at hand, tend to remain where they were born. A louse rarely, if ever, voluntarily leaves an individual in cold weather unless he has a high temperature or is dead. Consequently, the ordinary transference of lice from person to person is a purely mechanical process. Rubbing shoulders in a crowd, lice shaken on to the pillow or sheets, or on to the carpets and chairs of the bedroom during undressing, lice dropped as their host walks or sits down in shops, railway compartments, buses, etc., are examples of how the insects can be transferred mechanically and how typhus may be spread. It is interesting to observe how quickly people learn not to enter a crowd in a typhus area and take the greatest care not to brush against any passer-by.

Again, a louse finding itself in uncongenial surroundings, such as the outside of a garment on a cold day, rapidly moves in search of warmth and food. This is of great practical importance from an administrative point of view. It means that in regions where typhus is epidemic it is dangerous to wear either protective clothing or ordinary outer garments for more than two or three hours continuously. It is clearly impracticable to wear full protective clothing constantly whilst living and working in a typhus area. Ordinarily, one wears a macintosh coat and high boots or puttees. These outer garments should be changed as frequently as possible and disinfected. The most convenient method is to have two macintosh coats, one for the morning and the other for the afternoon. These garments are kept in two chests containing crude unwhizzed naphthalene. On returning from work for lunch the coat is dropped into one chest and the other garment worn in the afternoon. Protective garments (as described in Memo. 252/MED of the Ministry of Health) must invariably be worn for such work as cleansing the patient on admission to hospital, disinfestation of contacts, the disinfection of premises recently occupied by a patient, and in house-to-house search for cases. Even protective clothing, however, should not be worn for longer than a few hours, as otherwise lice will find their way in at the face aperture, the wrists, or the fastenings at the back, particularly where tapes and not zippers are relied on. Many deaths have occurred through failure to remember that both protective and ordinary garments only give temporary protection, and must be changed as frequently as possible.

Obviously, much must depend on the circumstances, but those who are willing to undertake this relatively simple precaution will greatly lessen their chance of becoming infected.

Lice become infected with typhus by ingesting *Rickettsia* from the blood of persons during the febrile stage of the disease—a period of about ten to fourteen days—the louse becoming infectious from the sixth day after feeding. In the gut of the louse the *Rickettsia* multiply rapidly and penetrate into the layers of the cells of the gut. Those that enter the cells multiply rapidly so that the cells become distended, and eventually burst. The louse dies about ten days after the rupture of the cells, but during this time the gut is packed with *Rickettsia* and large quantities are passed out with each dropping. These droppings, when dry, retain their infective power for a considerable time, and infection may occur from such dry faeces rubbed into the skin, falling on the conjunctiva, and possibly by being inhaled into the lungs.

There is, as far as we know, no regurgitation during feeding, and consequently infection of man occurs only indirectly through the bite of the louse. The saliva contains an irritant, and man acquires the infection when he crushes the louse in scratching and rubs the contents of the gut on to his skin and through the puncture made by the insect.

What are the practical points suggested by these facts?

Firstly, as the louse does not become infectious for six days after feeding on a typhus patient, rapidity in disinfection of "contacts" is of fundamental importance.

Secondly, a single louse is quite capable of infecting a man, and thus the first case of typhus may occur in an individual who is apparently louse-free. It is more than possible that if typhus were introduced into this country at the present time it would be by an individual who was quite free from lice, inasmuch as the traffic between the Continent and this country by air is limited to a type of individual who is unlikely to harbour vermin, but who might be infected abroad and develop the disease after arrival. Refugees and prisoners of war arriving in this country are in another category.

Thirdly, as might be expected, the nits (or eggs) of infected lice are not infectious, though it must not be forgotten that the outside of the eggs may be contaminated by louse faeces containing *Rickettsia*. Moreover, if the eggs happen to hatch out on a typhus patient the young insects will become infectious, and consequently every care must be taken to destroy all nits in addition to the adult insects at the time of disinfection. Furthermore, all cases of typhus admitted to hospital should be re-disinfested a week after the first delousing.

Fourthly, the possibility of infection by dry louse faeces must not be forgotten administratively. Whether or not masks are worn for nursing typhus, there is a general consensus of opinion that they should be worn invariably by those working in a dusty atmosphere where typhus has occurred—for example, in dealing with bedding, carpets, etc., in a house where a case of typhus has occurred. If a mask is used it must protect the conjunctiva as well as the air passages.

Fifthly, if the lice and nits are all killed in a room recently occupied by a typhus patient, what about the danger of dry louse faeces? Are *Rickettsia* bodies in dry faeces killed by the same temperatures or disinfecting processes as kill lice? Unfortunately, we have no certain answer to this question, though the problem is under consideration by a scientific committee at the present time. I would remind you that the technical difficulties of determining the biological characters of *Rickettsia* are very great. The organisms will only grow in the presence of living cells, and consequently have generally to be studied in the insect itself after it has been infected. In addition, *Rickettsia* appear readily to change their character under varying conditions, such as a change in the insect vector. Furthermore, lice frequently contain non-pathogenic *Rickettsia* of varying types, and, finally, the organisms are frequently exceedingly difficult to differentiate from other granules which occur commonly in tissues.

Pending the findings of the committee mentioned above, it would be premature to make any statement regarding such important administrative questions as the resistance of *Rickettsia* to cold, desiccation, gaseous and other disinfectants, etc. It has hitherto been assumed that measures that successfully remove lice and their eggs from clothing or blankets will also destroy any infective agent in droppings, but it should be emphasized that we have no scientific basis for this assumption. From a practical point of view, however, we do know that if all lice and nits are destroyed cases of typhus fever cease to occur.

Sixthly, closely associated with the question of the method of transference of the disease, namely, the louse and the dry faeces of the louse, is the problem of how the

disease is maintained in endemic areas. The answer to this is unknown. As you are aware, endemic typhus occurs with a regular periodicity, starting in November and continuing until the end of May or June. In an endemic area one of the most striking features is the complete cessation of all cases from June or July until the beginning of the following winter. Repeated and careful searching during the following few months invariably fails to reveal any cases of the disease. This raises the possibility that a proportion of patients remain as "carriers" of the disease, new cases again occurring with the onset of the cold weather, when the vectors—lice—again appear in large numbers. Another possibility is that living *Rickettsia* continue to remain in dried louse faeces and restart the disease when lice again appear in the cold weather. Finally, the possibility of exceedingly mild cases occurring in the inter-epidemic periods and being overlooked cannot be dismissed. Though there is much we do not yet know about possible methods of infection, experience shows, firstly, that effective destruction of all lice prevents an outbreak from continuing, and, secondly—and this is important from the point of view of widespread epidemics among a destitute population where it is not possible to kill all lice—the number of cases of typhus falls rapidly with the reduction in the number of lice amongst the population generally. In a highly-organized country where the health services are functioning normally we aim at the destruction of all lice on "contacts" and reduce as far as possible the louse infestation amongst the population. In the conditions under which epidemic typhus generally occurs we can only aim at reducing the louse population by every means in our power.

Seventhly, typhus fever is the only disease which may be met with in Britain which we know may be dangerous during the incubation period. Throughout the twelve or fourteen days after infection before the illness manifests itself, the patient through the infected lice he may be carrying constitutes a potential danger. It will be seen from this that a large number of "contacts" may be created, and why, once the disease is really epidemic in an area, it is useless to attempt to deal with more than the immediate (family) "contacts," and efforts can only be usefully directed to the reduction of the louse population generally.

Eighthly, it is no more dangerous to nurse a case of typhus which has been completely freed from lice than it is to nurse a case of typhoid fever or of plague freed from fleas. Nevertheless, it must be remembered that the blood of typhus patients is highly infectious, and consequently great care must be taken in collecting blood samples or in cases where the patient is coughing blood. Moreover, the excreta are, at any rate theoretically, infectious. The question of the possibility of infection by droplet infection from coughing is undecided, and some authorities urge the necessity of wearing masks for nursing, whilst others do not consider there is risk from this cause.

I do not propose to take up your time with a description of the ordinary methods of louse destruction, as most of them are familiar to you all. There are, however, a number of points in connection with delousing in the face of typhus which I think I might usefully recall briefly.

A first point is that whilst in ordinary delousing the destruction of every louse and nit is important, in dealing with cases of typhus it is fundamental that not a single louse or nit of a patient or "contact" escapes destruction. Moreover, a second delousing of patients should be carried out a week after the first to ensure that any young lice hatched from eggs missed in the first operation are killed.

Secondly, every care must be taken to transport the patient from his bed to the ambulance in such a way that lice are not shaken off him. This is best done by completely enveloping the patient in a large sheet ten feet long during the transit from his bedroom to the ambulance.

Thirdly, it must be constantly remembered that in all typhus work the strictest discipline must be maintained in respect of recognized precautions. This is specially the case in the most dangerous part of the work of control—the removal of the case to hospital, his disinfection in the admission block, the cleansing of the premises occupied by the patient, the disinfection of the bedding and clothing, and the search for secondary cases.

Fourthly, it is obvious that all "contacts" should be deloused at the same time and their beds and clothing disinfested simultaneously.

Fifthly, though ideally a disinfecting station should be reserved for typhus work,

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in practice this is rarely possible. If an ordinary disinfecting station is, however, used it must be closed for all other forms of work until all the typhus disinfection is done and the station has been thoroughly cleansed. If proper precautions are taken after disinfestation there is no reason why any efficient disinfecting station should not be used temporarily for typhus work. In every instance, it is essential to be absolutely sure that the disinfecting machinery used is in proper order and is correctly used.

Sixthly, the removal of lice from an individual by bathing is a purely mechanical process and except for the hair, which requires special treatment, can be carried out effectively with soap and a nail brush. The introduction of disinfectants into the baths is unnecessary and useless, as the strength of a disinfectant requisite to kill the lice in the short time of exposure would be too strong to allow of the bath being taken without damage to the patient.

One word on the use of insecticide powders in relation to typhus control. In ringing round small outbreaks of typhus in an organized community every effort must be made to kill every louse which may possibly be infected. Consequently, for this work, in my opinion, reliance can only be placed on well-proved methods of disinfestation which are known to destroy every louse. In cases, however, where the aim is only to reduce the louse population generally, or to prevent infestation, then insecticide powders certainly have their value.

I have not dealt with the methods of disinfestation necessitated by a big epidemic in a disorganized country, as these are not of such immediate interest to you. I might mention, however, that in this case reliance has to be placed on disinfestation with materials available in every village. Where, for instance, typhus is rampant over such an area as Poland, Roumania, Bulgaria and the Ukraine, its control is far beyond the possibility of disinfecting machinery or chemical disinfectants. Instructions explaining how best to cleanse persons and clothing have to be sent out by wireless or through the medium of Government leaflets to the mayors of the villages. Cutting of the hair and bathing can clearly be done by all. Cotton garments can be boiled. In the case of woollen clothing, the most generally applicable method of destroying lice under conditions of epidemic typhus is by the application of heat by ironing. This is simple in application, easy to explain to ignorant people, most households possess an iron, repeated applications are possible, and the work can be carried out at regular intervals by the woman of any household who is ready to protect her family. Ovens of locally-made brick or improvised current steam disinfestors may also be utilized, a description of how to make and use them being circulated by the central government.

Finally, in dealing with the louse and typhus I would remind you that the only vaccine for typhus which is known to be of some value in the field is that made by Weigl through the medium of the louse. It is prepared in the following way. Clean lice brought into the laboratory are inoculated by the anal route with *Rickettsia*. The *Rickettsia* is obtained either from the blood of a case of acute typhus or from the blood or organs of an infected guinea pig. The lice, which are fed on individuals who have had typhus and consequently have immunity, become infected, and the *Rickettsia* multiply rapidly in the cells of the intestine. The cells rupture and the *Rickettsia* are discharged in enormous numbers into the intestine. The lice die in nine to ten days from the infection, and fresh lice are again inoculated. The infected lice are dissected, their intestines removed in a sterile manner and ground up in solution with a small quantity of disinfectant. The reasons that militate against the general use of Weigl's vaccine are obvious. A large number of immunes are required upon which the lice can feed so that the production is in practice limited to countries in which the disease is endemic. The technique of infecting the lice is exceedingly difficult and requires long training. Finally, the number of lice required to produce a single dose of vaccines is considerable.

I have mentioned very briefly some of the more important points in connection with the relationship of the louse to typhus fever. For those of you who wish to pursue the subject further I would recommend, for a clinical description of the disease, Murchison's "Continued Fevers," and Harries and Mitman's "Clinical Practice in Infectious Diseases"; and from the entomological point of view Buxton's book on the "Louse," and a recent publication of the Museum of Natural History, by Dr. Smart, on "Lice."

The Louse in Relation to Typhus Fever

DR. J. J. PATERSON (Maidenhead) emphasized the fact that an outbreak of typhus might happen in this country, and therefore it was well to be prepared. He recalled the fact that typhus was once prevalent in this country and was known as "jail fever." He followed up the remarks of the lecturer by commenting upon the laboratory work in this connection which he had seen on the occasion of a League of Nations study tour in Poland some years ago, especially in connection with the preparation of a vaccine; but he emphasized that sanitarians should concern themselves with prevention rather than cure.

COUNCILLOR W. DAVIS (Battersea Borough Council) said that Dr. Mackenzie in the course of his paper had indicated that the head louse as well as the body louse might be responsible for the transmission of typhus. He said that a circular had recently been received by his borough from the London County Council relating to the increase of louse infestation among women and children. One of the factors to which this condition was attributed was the modern method of hairdressing and permanent waving. He thought that the condition referred to in the circular constituted a great danger as a possible means of transmission of typhus, and he asked if the Ministry was considering advising women against such methods of hairdressing and also of advising hairdressers to bring to the attention of the local authorities any cases where louse infestation was evident.

DR. F. J. BENTLEY (London County Council) asked if the Ministry of Health recommended cyanide for disinfection of the home after removal of a case of typhus, or alternatively, what method of disinfection was recommended.

MR. H. W. WALTERS (Kensington) said that he thought the Ministry of Health should give more precise instructions on the methods of disinfection to be carried out by local authorities should typhus become prevalent. He pointed out that combating typhus fever epidemics is not a local problem but, rather, a national one, and that it would be unsatisfactory if each local authority were allowed to take its own line in carrying out disinfection. He was doubtful whether there would be either uniformity or uniform efficiency, with the result that the danger of the disease spreading would be increased. He also made the point that there are methods of so-called disinfection which are by no means satisfactory, and he hoped that the committee of experts now considering the typhus problem would make careful investigation into the matter, and, having arrived at their conclusions, give instructions to all local authorities, which would ensure a thorough disinfection.

MR. C. J. LUCAS (Ware) asked whether Dr. Mackenzie would confirm that endemic typhus was prevalent in winter and spring and that the epidemic form might occur at any time.

MR. N. LIGHTOWLERS (Islington) asked what preventive measures were available to individual members of the general public to prevent infestation by lice, other than personal cleanliness? He also inquired if there was any repellent which an individual might use or wear upon his person, which would be objectionable to lice but not to human beings.

The following also took part in the discussion: Mr. A. W. E. Porter (Wandsworth), Mr. A. F. Saunders (Wandsworth), Dr. Charles Porter (London), and Mr. W. T. Creswell (London).

DR. MELVILLE MACKENZIE replied to the points raised in the discussion and MAJOR MCKENNY HUGHES, R.A.M.C., dealt with some of the questions asked.