Original Communications

PRACTICAL NOTES ON SCRUB TYPHUS IN THE FIELD

BY

J. R. AUDY

Hon. Lieutenant-Colonel Royal Army Medical Corps, formerly Officer in Charge, Scrub Typhus Research Laboratory (Imphal), South-East Asia Command.

INTRODUCTION

SCRUB TYPHUS (mite typhus, tsutsugamushi disease, or Japanese river fever) is distributed in patches over the whole Oriental region, including islands in the Indian Ocean, and extending into Queensland, just beyond New Guinea, and northwards to include Japan.

The object of the present paper is to draw attention to practical points in the prevention of infection in the field. For those who require detailed knowledge of various aspects, a guide to the recent literature is appended.

Symptoms of scrub typhus appear one to three weeks, usually ten to twelve days, after being bitten by an infected mite (*Trombicula akamushi* or *T. deliensis*). A severe bout of fever follows, lasting two to three weeks and associated with a mortality which varies according to the virulence of the local strain, the condition and age of the victim, and the immediate nursing facilities.

When numbers of men enter endemic foci, cases of scrub typhus may occur in epidemic proportions and, unlike most sickness and battle casualties, estimates cannot be made in advance. At any moment serious local setbacks may be encountered during a campaign. Scrub typhus casualties may fill up the forward hospital beds at awkward times, a likely circumstance because outbreaks usually coincide with occupation of new territory, and because the immediate forward nursing of these cases is very important and greatly improves the prognosis.

Innumerable examples could be chosen to illustrate this. East African units of less than Brigade strength suddenly suffered no less than 756 cases in January 1944 after exposure to an infected focus in South Ceylon for only four days. Over 900 more cases contracted in the Imphal-Kabaw valley area from June to December raised the scrub typhus casualties of the 11th East African

1Now at the Institute for Medical Research, Kuala Lumpur.

2 *Tsutsuga-mushi* = dangerous bug or mite. The first studies were made in Japan where this disease is a very distinctive fever in certain notorious valleys. Apart from this, there is no association with Japan, and scrub typhus is more particularly an Indo-Malaysian disease.
Division to over 1,600 in twelve months, while one battalion which approached Kalewa on the Chindwin passed through an infected area and had an outbreak of 85 cases of scrub typhus coinciding with its arrival at the objective. The 5th Indian Division also suffered about 900 cases during the drive down the Tiddim Road, and in two months one unit’s scrub typhus casualties amounted to 18 per cent of its strength, 5 per cent of the unit dying of this disease.

Morale was at one time considerably lowered by this disease, and men whose units had been in contact with scrub typhus were often more afraid of clumps of grass than they were of the enemy. This attitude will never be marked again, but the effect of scrub typhus on military calculations remains.

**Localization and Variation**

The patchiness in distribution of scrub typhus is on two scales, firstly into *endemic areas* which may extend over a few to several thousand square miles, the classical examples being the restricted infected regions of certain rivers in Japan; secondly, into "*typhus islands*" or individual infected foci, which may be restricted even to a few square yards. The Japanese call such infected foci *yudokuchi* or "noxious areas." If a large number of typhus-islands, or a proportion of very heavily infected typhus-islands, occur in an endemic region, it is usually called hyperendemic, but a single focus may give rise to an alarming proportion of cases even though it may be in a region of generally low endemcity. Casualties are consequently most difficult to predict.

The disease appears to be most sharply localized in scattered "islands" in the plains of India, the Dry Zone of Central Burma and in Japan, and possibly Central China, while it appears at present to be poorly established in north and west Ceylon, and to be restricted to only a small part of Queensland in Australia.

Both theory and observation suggest that scrub typhus should gradually become more widely established and that there is a natural limit towards which the number and extent of typhus-islands in an area tend to increase. It is certain (a) that infection can persist in the same spot for decades; (b) that the extent and endemcity of any focus may vary, perhaps considerably, from year to year; (c) that the disease may apparently appear *de novo* in a potential focus, and may also, but rarely, apparently disappear, and (d) that the actual virulence and even antigenic properties of the organism vary from place to place, and quite possibly in the same place from time to time.

**The Aetiological Agent, Rickettsia Tsutsugamushi**

The infective agent, *Rickettsia tsutsugamushi* (= *R. orientalis*), usually appears as diplococcoid intracytoplasmic bodies somewhat smaller than a gonococcus. These occur occasionally but naturally as symbiotes in the tissue cells of certain trombiculid mites, and invade temporarily the blood and tissues of a number of animal and avian hosts on which the mites are regularly parasitic, causing mild symptoms or none at all. Such hosts, it is assumed,
may, by acting as temporary "reservoirs," serve to boost infection amongst the mites.

The organism pervades all the tissues of the mites (in common with the related rickettsiae of tick-typhus) and once present is passed, to an unknown extent, through the gonads to the eggs and so to following generations. This congenital or trans-ovarial transmission of infection through parent mite to offspring has been experimentally confirmed in both the species of vector mite. The proportion of infected mites in any endemic area is not accurately known but evidence suggests that (a) this proportion is related to the intensity and duration of the mite-host-mite cycle in an infected focus, and (b) as with Rocky Mountain spotted fever infection in ticks, the usual rates are none or a few per thousand, but the proportion may rise to well over 10 per cent in hyperendemic foci.

THE VECTOR

The vector is for practical purposes best considered as a single variable species occurring in two extreme forms and several intermediates, its range of course coinciding with that of scrub typhus. The form Trombicula akamushi occurs in the east and north-east part of the range, while the form T. deliensis is poorly represented in the north-east but extends from Queensland to India. In the region from Malaya to New Guinea and the Philippines, the two subspecies overlap, and either may be an effective vector in adjoining foci, or they may even occur together in the same focus. It is possible that another species might occasionally transmit infection in an endemic area but this must be quite exceptional and of no practical importance.

The mites belong to the family Trombiculidae, of which the six-legged larvae are parasitic and are known as "chiggers" (an American name) and as "harvest mites" in Britain. Those which attack man have various local names. After feeding on an animal or bird, the larvae go into the soil, pass through a pupa-like stage, and become eight-legged nymphs and finally adults, about 1 mm. long, which live in the soil and lay eggs there if conditions are suitable. The nymphs and adults of the vector prey on various soil denizens: they are not vegetarian, as was formerly supposed. The whole cycle probably takes eight to twelve or more weeks in nature.

The minute larval vector mites can readily be seen with the naked eye or a hand-lens, usually forming reddish orange clusters in the ears, on the thighs or near the genitals of all kinds of animals frequenting the scrub. Rats, squirrels, tree-shrews and such birds as crow-pheasants and quail are the commonest hosts, and presumably all these may act as temporary "reservoirs." Other chiggers are white or pale yellow or bright scarlet and sometimes rather large. Orange-red or orange-ochre coloured mites in any numbers on rats are usually of the vector species. An average of 25 per cent of rats lightly infested,

1American authorities are proposing a subspecies, T. akamushi deliensis. Accepted synonyms for the vectors are: T. walchi = T. vanderghinstei = T. deliensis and T. fletcheri = T. obscura = T. akamushi.
or of 25 vector mites per rat, appears to be roughly the lower danger limit. Larvae may remain alive for at least one to two months without a feed.

Several species of chigger cause violent irritation some time after attendant, like the harvest-mite. This irritation, "scrub-itch," can be most disturbing. It is quite unrelated to scrub typhus. The following species proved troublesome to troops in Australia and New Guinea: Trombicula minor (= Eutrombicula wichmanni), Schongastia pusilla (= S. schüffneri), S. blestowei (= S. vandersandei),1 while other Australian scrub-itch mites are T. samboni, T. sarcina and Acomatacarus australiensis. The first two species have both been mooted as possible vectors in New Guinea and Sumatra, but they are absent from most infected foci and very abundant in many non-endemic areas.

Seasonal Incidence and Moist Foci

The larvae appear seasonally in a monsoon climate, the main peak being a month or two after the onset of the rains, while the larvae are suppressed by prolonged dryness or extreme cold. This seems to be due to a hibernation of the adult mites in dry soil: larvae persist in moist foci throughout the dry season (Audy, 1949c). These perennially moist foci such as seepages, stream sides and moist gullies must therefore be avoided. There is usually no distinct seasonal incidence in equatorial climates but the larval population will be found to drop during continued dry spells.

Effect on Man

Observations by McCulloch (1946), the U.S.A. Typhus Commission and the Scrub Typhus Research Laboratory, S.E.A.C., suggest that the maximum risk to man obtains in the following conditions:

(a) Sitting or lying, or standing about, on infested ground—not walking through it.

(b) Periods of slight rainfall, or no rainfall but heavy dew, following heavier rainy spells—not during waterlogged conditions or repeated heavy storms nor after long dry spells.

(c) The period while dew or rain is evaporating off the ground, until the heat of the day starts to become intense—say up to 10 or 11 a.m. The risk is greatly lessened throughout the day, especially on sunny days, to rise again with the rising humidity in the late evening. Activity continues through the night, especially if warm.

The bite of the mite is usually unnoticed (see Fuller, 1947) but (presumably when it attaches in close relation to a pain-corpuscle, or when it rapidly produces a horny sucking-tube in the tissues) it may produce a very distinct pricking sensation when touched. The scrub-itch mites, however, produce a delayed but intense reaction.

1The names in parentheses are the correct equivalents as accepted by Womersley and the American authorities.
EFFECT OF CAMPING

The proper clearing and "civilization" of a camp produces conditions unfavourable to the mite, probably largely by drying out and compacting the soil, so that the risk of occupying an infected site drops rapidly after the first week or so. There is, however, risk from two sources, as was learnt in both Assam-Burma and New Guinea: (a) the persistence of mites in small isolated clumps of grass within the camp or in the periphery, and (b) in the event of encouragement of rats near such patches, or in the repeated abandonment and reoccupation of sites, a period of neglect intervening. Evidence was gained during the war that the endemicity was rapidly increased in camp sites following abandonment to weeds and rats.

OUTBREAKS

The incubation period ranges about twelve days, to which we must add a diagnostic interval, which is now happily shortened. Even so, the recognition of an outbreak often takes some three weeks after occupation of the infected site. By this time the risk is usually greatly reduced or eliminated and most of the cases are either febrile or incubating, so that nothing can readily be done to prevent the main outbreak. As the outbreaks cause the greatest disruption of services, our first effort should obviously be directed at shortening this interval between infection and the diagnosis of the first case or two, especially as chloromycetin is a drug which could successfully abort the remaining infections.

There are four requirements in avoiding outbreaks: avoidance of infected foci when possible; the proper and immediate clearing of the occupied site; the early rousing of suspicions after occupation; and the early diagnosis of cases and their notification to the units. We may take these points in turn; but as the practicability of all these measures varies very greatly with the circumstances, there is clearly no point in doing more than draw attention to a few features. It will be noted that there were 600 cases of scrub typhus in Burma in 1945 in spite of the fact that dibutylphthalate was widely distributed and fully advertised and was applied on official parades. The need for avoidance will always remain.

(a) Avoidance.—The conditions and situations in which most of the endemic foci occur are summarized below. If there is time and opportunity, the site should be "surveyed," for useful information can be gained even in one day, as described briefly below.

(b) Clearing.—Immediate proper clearing by fully protected personnel, preferably by bulldozer, is most important. Sometimes it is possible to wait for a long dry spell before clearing a site in an endemic area.

(c) Early Suspicions.—For the first few days, it is wise to look for mites which may crawl on to boots after standing for a few minutes and pairs of men may be detailed to do this for a short time before or after breakfast. This must be done in the cool of the morning while the ground surface
humidity is high. If the vector mites are found on boots, the area is almost certain to be dangerous, as this is not an efficient method except with considerable populations. The very patchy distribution of the mites must be borne in mind. Negative boot-catches are meaningless. All mites seen must be picked up with a moistened bristle or grass blade and identified.

It is sensible always to look for rat burrows, while in many types of undergrowth, rat-runs may be picked out by the keen observer. Faecal pellets may be found. All these give a very good pointer to the rat population.

(d) Diagnosis and Notification.—It frequently happens that the unit receives its first notification by signal or post after a diagnosis has been confirmed. In the earlier days of the war this was sometimes withheld until serological confirmation was obtained. The local organization should be such that clinical diagnoses are communicated immediately to both the unit and the responsible hygiene officers or R.M.O.s. For the hygiene officers, a graphic method of presenting the case incidence is essential, but the writer has noted that the data on spot-maps were frequently so held up by various causes as to lag a month behind the dates of actual infection of the first cases.

The units require early notification so that R.M.O.s and others can anticipate further casualties and take appropriate steps. It is most important that following units gain by the experiences of those preceding them. Rapidly advancing units of the 14th Army and Burma Command in several instances took over sites which had recently caused a crop of cases among the previous occupants.

The hygiene officers amongst other things require a general picture of the endemicity of the areas successively occupied by troops, the patchy distribution of the disease being borne in mind. The accurate pin-pointing of all infected foci is most important, and on active operations this might best be effected by coaching patients with NYD fevers, that is, by the R.M.O.s assuming the case to be one of scrub typhus, questioning the patient in an effort to pin-point the presumptive infection, and then instructing the patient clearly as to where infection was probably picked up—if it turns out to be scrub typhus and if he has asked about it. This would eliminate the extreme vagueness so common when questioning sick men.

**Methods of Survey**

The simplest methods of survey involve inspecting the mites on animals living on the site, and the following account is confined to these in the hopes that it may help hygiene officers and maliarologists who may be called upon to make decisions in scrub typhus areas. The risk of infection at any time is related to the population of the vector species as estimated by the numbers found on rodents and short-ranged birds such as quail and crow-pheasants.

(a) Collection.—Attempt to trap (alive if possible) and shoot the largest number of rodents and birds from each patch of terrain concerned. Examine all killed hosts preferably within an hour or so, for many larvae will leave
the dead hosts. Inspect the insides and edges of the ears and around the vent and genitals, the teats, thighs and under the wings for clusters of mites looking like tiny eggs. Animals may be carried for a time in tough paper or cloth bags which are afterwards searched. A magnifying electric auriscope is most useful for inspecting ears in the field. Mites are best collected (i) by scraping colonies out of ears with a Volkmann's spoon or similar instrument, and floating in water overnight so that the mites may struggle free from the debris, or (ii) by excising ears and pieces of infested skin, pinning these to the corks of specimen tubes, leaving overnight for the mites to detach and adding some 70 per cent spirit the next day, or (iii) by suspending the dead animals by the tail over dishes of water, when the mites will shortly be found floating.

(b) Identification of the hosts is not essential but should always be done if possible. The following records should be made even if skull and skin are not preserved: measurements of nose-tip to tail-tip, tail, car and hind-foot excluding claws, colours and general description, locality and habitat. Skulls are best dried with the flesh on and preserved from insects.

(c) Identification of the mites may be done provisionally in lactophenol using a 4 mm. objective. Although the identification of trombiculids is a job for an expert, the vector in endemic foci is nearly always a dominant and frequent species on rats, and confusion with similar uncommon species is thus less probable. Identification is based on the characters of the larval dorsal shield or scutum, the edges of which may be faintly discerned immediately behind the mouth-parts and between the two red eyes. Behind the scutum are rows of dorsal setae. The most conspicuous feature of the scutum is the pair of chitinous rings or pores from which arise sensory organs (sensillæ) which may be clubbed, globular or filamentous; these often become detached, especially if clubbed. There are typically 4 “corner” setæ (antero- and posterolaterals) and 0, 1 or 2 antero-median setæ, while sometimes dorsal setæ are included in a backward extension of the scutum (see fig. 1).

The generic groups may be distinguished thus:

(1) No anteromedian seta: sensillæ swollen; scutum often convex behind and encroaching on the dorsal setæ; widespread in small numbers, commonest in forest

Gahrliepia
(Walchia)
group.

One anteromedian seta (making 5 scutal setæ and 2 sensillæ); widespread and common

Leeuwenhoekiid
group.

Two anteromedian setæ; rare on rodents

Schöngastia
group.

(2) Sensillæ globose or clubbed

Sensillæ filamentous

Trombiculidae
group.
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Fig. 1.—*Eutrombicula wichmanni* (Oudemans), larva. (Synonyms: *Trombicula minor* Berlese; *T. hirsti* Sambon; *T. pseudoakamushi* Hatori). From a rat, near Kuala Lumpur. A scrub-itch mite common in Queensland and New Guinea but also found from Assam-Burma to Sumatra and Formosa. The major hosts are birds. Not known to be a vector.

Vectors.—The larval vectors are orange or reddish-orange, becoming paler with engorgement; not bright red, scarlet, vermilion or white. The site of election is within the conchæ of rats’ ears. The scutum is rectangular, with the sensory bases 22–38 μ apart and slightly anterior to the posterolateral setae (“PLs”). In *deliensis* the hind edge of the scutum is some 12 μ behind the line of the PLs and the dorsal setæ number 28 fairly regularly, in rows 2, 8, 6, 4, 2. In *akamushi* the hind margin is only half this depth behind the PLs and the dorsal setae number 30–40 in rows of 2, 10 (or 8), 8, 6, 4, 2. Compare specimens with the photograph, fig. 2. Measurements covering the known extremes are omitted as they embrace several other lesser known species. Confirmation of identities may be obtained from the British Museum (Natural History), Mr. H. Womersley, South Australian Museum, Adelaide, or the Scrub Typhus Research Unit, Institute for Medical Research, Kuala Lumpur, Malaya.¹

(d) Interpretation.—Heavy infestation by any species of trombiculid mite should raise suspicions. Infestation by *T. deliensis* may be roughly interpreted as follows, always making allowance for such events as a recent spell of dry weather:

¹The Scrub Typhus Research Unit is prepared to send named slides of *T. deliensis*, *T. akamushi* and *Euschöngastia (=Ascoschöngastia) indica* to those requiring specimens for teaching purposes or to those who intend to collect trombiculids.
FIG. 2.—Trombicula akamushi (Brumpt), a larva from the ear of the vole Microtus montebelloi from Niigata district, Japan. Collected by Colonel C. B. Philip and presented to the writer. The scutum is characteristic of T. akamushi but the dorsal setae (of which one set has been picked out in black) are 2, 8, 6, 8, 4, 2, i.e. intermediate between the numbers typical of T. akamushi and T. deliensis. These setae must be counted carefully and may be confused with those on the venter. Intermediate forms are not common.

(i) 1 in 10 rats1 infested, or an average of over 5 mites per rat: further investigation advisable, to make sure a restricted focus is not being missed.

(ii) 3–4 in 10 rats infested, or over 15 mites per rat: some risk of scrub typhus likely in an endemic neighbourhood.

1Mice and the small rat, Rattus exulans (=R. concolor) are often relatively lightly infested and, except perhaps in the Pacific theatre, negative findings on these should be ignored. The best index is to be gained from the locally prevalent sub-species of Rattus rattus. A most useful description of, and keys to, the commensal rats are contained in a paper by Harrison (1949).
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(iii) 6 or more rats in 10 infested or over 50 mites per rat: may be a hyperendemic focus—avoidance, full investigation or full precautions to be advised.

(iv) A single rat heavily infested (100 or more) immediately makes the risk positive.

Another rule-of-thumb guide, involving no identification of mites, is that during the typhus season (July to October inclusive in Burma and Assam) the infestation range which included most endemic foci of practical importance was the presence of 20 per cent or more of rats with orange-coloured colonies of mites in either ear, one-tenth of an inch or more in diameter.

Some hosts, such as birds in the scrub, may be relatively much more heavily infested than the rats in the same site. The rats are basically responsible for the ground-infestation, but a bird or other creature may pick up large numbers of larvae by ranging more widely.

“Typhus Scrub”

Scrub typhus is not strictly related to any species of plant or to any special vegetation, but it is related to terrain. Ecological studies made during the War suggest that, in spite of the difficulty and even risk of giving rule-of-thumb descriptions, the following may be taken as a useful practical guide to the particular types of terrain which are most dangerous.

Apart from its fringes, or natural or artificial interruptions, evidence suggests that virgin forest, and probably the depths of secondary forest with a leaf-litter floor, are generally free from risk of infection. So also are regular clean-cultivated areas.

(a) Man-made waste land, of three types:

(i) Rural—abandoned clearings, usually covered in grass and other weeds, especially if restricted and often especially round the edges. More or less shrub or tree growth may be present, but the grassy and weedy floor is the proper index.

(ii) Domestic or “suburban” waste land—neglected patches in or on the outskirts of villages and even towns, examples being the ground of Fort William in Calcutta and Fort Dufferin in Mandalay, and subsoil drainage bays in Kuala Lumpur. Included in this group are of course abandoned villages, camps and homesteads, as well as squatters’ areas.

(iii) Neglected native gardens or plantations—including weedy clearings in the latter.

(b) Water-meadows—grassy, but not swampy, river and stream banks (especially in monsoon climates).

(c) The “Hedgerow” type of feature, by which is implied firstly the region where grass or open scrub is flanked by woodland, and secondly, a range of features from a simple bushy hedgerow to the narrow gallery or belt of forest which, in deforested areas and frequently in and below foothills, is commonly left following water courses or ravines.
Sometimes this type of feature is broken up into bushy or wooded clumps, such as may sometimes be found in old sugar-cane fields, on cleared hillsides or amongst paddy.

**Prevention by Personal Protection**

In concert with antimalarial measures, the entomological control of scrub typhus is directed firstly towards personal protection by the treatment of clothing with mite-poisons (see McCulloch, 1946), and secondly against the mites themselves on the surface of the ground. The acaricides available are as follows: they are mite-poisons and not mite-repellents:

- **DMP** (di-methyl-phthalate), present in "Skat" and most other bottled "insect repellent." A rapid poison lasting only one or two washes, slightly oily and almost odourless.

- **DBP** (di-butyl-phthalate) is heavier, slightly more oily and less rapid in action but lasts some six or seven washes and is therefore most practicable. Both these phthalates are in great demand by the plastic and other industries.

- **BB** (benzyl benzoate) has a distinct smell, is rapid in action and lasts as long as DBP. DBP and BB in equal parts make a most useful mixture.

The dosage in all cases is the same.

All these agents are irritant to the eyes and tender parts, but this is least noticeable with DBP. BB is particularly irritant to certain individuals. A popular insect repellent contains DMP, Rutger's 612 and indalone ("6-2-2"). The presence of DMP is usually stated on the label. Powdered sulphur could be used if necessary. Benzil and other agents are extremely effective (Snyder and Morton, 1946).

**Application.**—The standard dosage is a teaspoonful to a pair of socks, or an ounce to a set of socks, trousers and shirt. This gives 90 per cent or more protection against scrub typhus or scrub-itch. DMP should be reapplied after laundering, but DBP lasts three boilings or six warm-water washes by hand.

A few drops in the hand, rubbed once to spread between the palms, is applied directly to the inside of the garment. Four such smears suffice for each side of each leg of the trousers with 2 extra for turnups and 10 smears for the rest of the garment. The Technical Memorandum on Scrub Typhus (9.12.46) of the Director of Medical Services, S.E.A.L.F., gives the following numbers of smears: socks, vests, cotton underpants and puttees, 6 smears each; trousers 30, blouse 25 (5 to each arm), making a total of 91 smears using 2 oz. of fluid. For personal use, McCulloch suggests applying DBP immediately before laundering to avoid the unpleasant collection of dust by the agent, and for home use recommends a shaker containing one part phthalate to two or three of water.

Dipping in 5 per cent emulsion is most useful. Use 8 oz. of DBP or BB per gallon of water containing 3½ oz. soap; dip the clothes, wring out lightly and dry. A U.S. Army mixture consists of BB, DMP and a soluble emulsifier in the proportions 9:9:2, diluted with 17 parts of water before use.
Native labourers may be encouraged to wear half-hose or sock or stocking tops, well impregnated with DBP and DMP, like sleeves on their calves and arms. A blanket impregnated with 6–10 oz. of DBP—BB mixture, or with gammexane at the rate of about 3 grammes of the gamma isomer per square foot (vide Horton et al., 1948) will be most useful in some circumstances and would probably be effective for several months.

**Vaccines and Chemoprophylaxis**

The vaccine from lungs of cotton-rats prepared as a wartime emergency—"Operation Tyburn" (Buckland et al., 1945)—went out of production in 1945. This vaccine was a success in the laboratory but circumstances prevented its evaluation in the protection of man and it is too costly to produce commercially. Experimental vaccines are being tried out from time to time. One may hope for little more than a great reduction of mortality and a mitigation of the clinical course.

Trials of chloromycetin (Smadel et al., 1948, and this Journal, 1949) have shown that this drug is a promising chemoprophylactic and details of its use have been released.

**Prevention by Field Control**

(a) **Clearing.**—Clean clearing the ground, especially if this includes scraping off the top inch or so of soil, leads to a great reduction or even elimination of the mites. Adult mites, and presumably whatever larvae are present, are little affected by firing undergrowth, but this is a useful prelude to ploughing or clearing as it encourages drying. The actual clearing is a very risky occupation and is best done by bulldozers. The choice of dry season, dry spells, and the latter part of the day for clearing reduces the risk. Particularly for temporary sites hurriedly prepared, clearing should be combined with chemical treatment when this is feasible. In more permanent camps, attention should be paid to neighbouring scrub, and it is suggested that putting the land under cultivation is an economical measure.

(b) **Chemical Methods.**—Petroleum and gammexane are the only two agents at present known to be of practical value. Petroleum, crude engine oil or diesel oil applied at the rate of 40 gallons per acre of soil effectively controls larvae for a few days, which allows time for clearing the site. Applications may be repeated, using a knapsack or similar sprayer, the nozzle being kept below undergrowth with flat leaves or fronds. Petroleum was first used in Japan (Kawamura, 1926) but its value was properly established by tests made by Bushland (1946).

Gammexane is best applied in fuel oil or mixed with an inert dust, and is undoubtedly effective, while other agents are being tested by American workers. Linduska and Morton (1947) recommend dosages of 4–6 lb. per acre of crude benzene hexachloride (12 per cent gamma—i.e. ½–¾ lb. gamma isomer per acre), mixed with three times its weight of talc or as 3 per cent in fuel oil. This gave a 95 per cent reduction in an hour or so lasting for three
to four weeks. McCulloch (1947) found the following to be effective for a fortnight against a tenacious scrub-itch mite in Australia: 1–1 1/2 oz. per 6 square yards of 14 per cent of BHC in dust, equivalent to 1–1 1/2 lb. of \textit{gamma} per acre. Dosages of 1 lb. \textit{gamma} per acre should be fully effective against the vectors if applied in fuel oil.

(c) \textit{Anti-rat Measures}.—Persistent anti-rat hygiene is of great value in discouraging the establishment of scrub-typhus on a long-term basis, and its importance in the long run cannot be overestimated.

Active anti-rat measures in order to reduce an actual risk must, however, be undertaken only after careful consideration as they may prove quite uneconomical.

At any moment, the population of larval vector mites comprises two fractions, those free-living on the ground, and those feeding on various hosts such as rats. If the feeding of the latter fraction is interrupted by the death of the rats, a number of the attached mites may still be capable either of reattaching to another host or completing the life-cycle, while the remainder will die from various causes.

Laboratory observations suggest that as many as a third or a half of attached larvae might, on the death of their hosts, either reattach owing to insufficient feeding, or having had more than a threshold feed may become viable nymphs. Moreover, these larvae which are likely to remain viable appear to leave the host soonest after death, within a few hours. It is therefore economical to trap rats alive and destroy them properly so that their parasites do not escape. When dead rats are collected in endemic foci, the soil under and immediately around them should have gammexane stirred into the surface with a stick.

A second point is that a reduction of the rat population cannot reduce the generation of larvae due to appear.

A third point to consider is that rats exercise an important function in "mopping up" free larvae, so that anti-rat measures adopted too early will actually increase the risk of scrub typhus because a larger number of larvae will remain free to attach to any alternative hosts which happen to contact them. On the other hand, if adopted too late, a large number of larvae will have fed and returned to the soil, later to give rise to a second generation of larvae.

It thus appears that in monsoon climates such at that of Burma, anti-rat measures must definitely not be adopted in \textit{anticipation} of the "typhus season." Prebaiting should be begun at such a time that the greatest number of rats will be killed during and at the height of the first infestation peak, a month or so after the rains start. For the same reasons, such measures should not be adopted immediately before or during clearing operations. The best time is probably immediately after clearing, when skilful prebaiting might also attract the maximum number of rats.

In equatorial climates where seasonal changes are not marked, anti-rat
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measures may probably best be adopted a month or so after the peak in pregnancy-rate amongst the rats, if this exists and is known. It is not possible yet to decide whether measures taken and continued some six months before clearing operations start will reduce the risk to labour or not, but this is worth trying provided the interval is not shortened.

If men are to be exposed after anti-rat measures, some attention should be given to the sites used for prebaiting. The pattern of ground-infestation by mites is related to the pattern of behaviour of the rats, and if the latter is radically altered, as it might be by the deviation of many rats to bait on new site, a large number of larvae in established habitats might not be picked up, and this might increase the scrub typhus risk. As far as possible prebaiting sites should coincide with feeding sites normally preferred by the rats.

(d) Attacking “Centres of Dispersal”—All endemic foci must be regarded as potential centres of dispersal of infection. Typhus-islands such as those common in and around villages, towns and estates may thus be of practical importance as “reservoirs” of infected mites. Hedgerows and narrow forest belts, seepages and moist water meadows may serve as sanctuaries for rodents disturbed by scrub-fires or shifting cultivation, and consequently as hyper-endemic foci ignored by the local population. This is of practical importance, for it is not sensible to attempt to control a troublesome focus if an adjacent endemic “reservoir” is left uncontrolled. For example, in the case of the Oil Palm Estate near Kuala Lumpur described by Lewthwaite (1930) it is probably an essential part of control to attack the forest fringe at the perimeter, although no labourers may get infected there.

Both survey and control should therefore extend beyond the actual site of exposure about which there is direct concern.

Summary

(1) Points likely to be of practical value to hygiene officers and epidemiologists are collected together and supported by a guide to the more detailed and comprehensive literature on scrub typhus.

(2) Some of the epidemiological points stressed are the localization of infection to endemic districts containing sharply restricted foci; the presence of a single vector species with two chief forms or sub-species, and the probable unimportance of other species of mite, and particularly of “Trombicula minor,” a scrub-itch chigger; the reduction of questing larvae (and consequently of the risk of infection) with lowered humidity associated with the time of day, with dry weather, or with operations such as clearing the undergrowth; the importance of avoiding outbreaks by taking steps before the first few cases appear, by which time it is usually too late to prevent the main bulk of casualties.

(3) Simple methods of survey are noted, comparable in method and object with malaria surveys. Notes are made on the prevention of infection by avoidance, individual protection by chemical treatment of clothing, and field
control. The value of gammexane on blankets and on the ground is stressed. Vaccines, other than experimental, are not available and there are many obstacles in the way of their production—one being the variation which exists between rickettsial strains. Chloromycetin is known to be an effective chemoprophylactic.

A GUIDE TO THE RECENT NON-CLINICAL LITERATURE ON SCRUB TYPHUS

The following papers are selected because they contain fairly complete accounts and, often, comprehensive bibliographies, while the subject matter is not purely technical and is likely to be of reference value to the workers for whom the present paper was written. Descriptions are added where the title is not fully explanatory.

(1) COMPREHENSIVE WORKS ON RICKETTSIA AND RICKETTSIAL DISEASES

MOULTON, F. R. (1948) (Editor) *Rickettsial Diseases of Man*, Washington. (27 papers; 3 confined to scrub typhus; others on vectors, reservoirs, relationships, nomenclature, treatment and serology.)

RIVERS, T. M. (1948) (Editor) *Viral and Rickettsial Diseases of Man*, Lippincott. (8 papers on typhus fevers; 8 papers on rickettsial subjects; 1 on scrub typhus by Smadel.)


(2) REVIEWS OF LITERATURE ON SCRUB TYPHUS


(3) EPIDEMIOLOGY

(a) Reviews and General Descriptive Accounts


(b) Epidemiological Investigations in Indo-Burma Theatre

AUDY, J. R. (1949a) *Loc. cit.* (General epidemiology and topography.)


War Office, Army Medical Directorate (1947) Scrub typhus investigations in South East
Practical Notes on Scrub Typhus in the Field


(c) Studies on Trombiculid Mites (Excluding Purely Systematic Papers)

(4) Control
— (1947) The adaptation of military scrub typhus mite control to civilian needs, Med. J. Aust., April, 449-52. (Review plus field trial of gammexane; scrub itch mites in Australia.)

TEXT REFERENCES
The following references made in the text are not included in the above list.