Treatment Resistance in Louse Control

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While there are problems facing the physician in treating an individual patient for lice, such as choice of pediculicide, from the public health view our greatest concern is lice control in entire populations. This paper deals mainly with problems encountered in mass delousing campaigns. These may be associated with the organization and implementation of mass delousing under difficult conditions or the problems of louse resistance to insecticides.

PROBLEMS OF MASS DELOUSING PROGRAMS

In the developed world today, the problem of delousing involves mainly individual patients and relates largely to head lice (Pediculus humanus capitis) or crab lice (Pthirus pubis),13 “Treatment” rather than “delousing” is the appropriate descriptive word and control is usually achieved through the prescription of a proprietary compound or formulation. The situation may vary for a school nurse dealing with an “epidemic” of head lice where perhaps 10 or 20 per cent of the children in a class may be infested. Treatment is often performed by sending advice to parents on what insecticide to purchase for the child or his siblings. In the case of crab lice infestations, treatment is inevitably of the individual consulting the physician or, often, one who self-medicates using a pediculicide purchased at a pharmacy.

Controlling lice infestations is different in those countries of the developing world where lice and louse borne diseases are prevalent. Mass delousing during wars, natural disasters, or mass population displacements acquires a dimension different from that faced by the physician treating a single patient.
Body Lice

Although body louse (P. humanus humanus) infestations are common among part of the population in many countries, mass delousing campaigns are usually performed to control epidemic or threatened outbreaks of louse-borne disease. Disease outbreaks may occur when reasonably large numbers of nonimmune individuals in a population are infested by body lice and a human reservoir of the disease is present (the role of an extra-human cycle remains unproved). Endemoepidemic situations occur in countries such as Ethiopia, Burundi, Rwanda, and Ecuador where body lice infestations are common and typhus or relapsing fever continually are transmitted in the human population.

Epidemics may occur during wars or major civil strife or after natural disasters (earthquakes, floods and famine); in these the normal conditions of hygiene and sanitation of the individual and community are disrupted. In such disturbed populations infestations can build up quickly, if no measures are taken to prevent them; should the disease organism be introduced into the infested populations, an epidemic outbreak of disease may quickly follow. The great epidemics of typhus and relapsing fever in 1914-1918 and the lesser but still serious outbreaks during 1939-1946 and during the Korean war are examples.

While the preceding situations have as common features the presence of louse-borne disease, the manner in which a louse control program must be organized to control an epidemic, or the threat of such, will differ considerably between an endemoepidemic zone and a sudden epidemic outbreak; consequently they will be considered separately. The measures outlined deal only with the organization of vector control operations and not with vaccines nor with therapeutic measures to cure those already ill.

Lice Control in Endemic Situations

Several features common to all foci of louse-borne disease affect the organization of control operations. The foci are characterized by occurrence in the poorer areas of the country, often in remote areas, difficult to access. Lice infestations are tolerated by the population; there is usually little understanding of the link between body lice infestations and the presence of disease. Often there is suspicion of an outsider and a reluctance to undergo treatment unless its purpose is clearly explained.

There must be good liaison with the groups responsible for epidemiologic surveillance. Vector control should be started in those areas where the most disease is occurring or where the threat of disease is greatest. The urgency of the control measures and the planning will be affected by whether the objective is to halt transmission of disease or
Problems of Mass Delousing Programs

to reduce prevalence of lice infestations to a point where disease transmission becomes unlikely. When the objective has been set, the following steps should be taken.

Survey of Lice Infestations

The success of a vector control program must be measured by the extent to which it has reduced the vector population and reduced transmission of disease. It is necessary to have information of the prevalence of infestation in the target population prior to beginning control operations. The larger the number of people surveyed the more accurate the information obtained. When there is neither time nor resources to perform an extensive survey, a reasonable cross section by age and sex should be obtained; in addition to recording the presence of body lice, the sex, age group and occupation of the individuals should be noted. Opportunity might be taken to record the prevalence of head lice and scabies infestations. Note should be made of the type of clothing and the frequency with which it is changed or washed. Finally, the number of people in an area to be treated should be determined as a guide to assessing the amount of insecticide required. The sensibilities of the population must be considered; it is essential that a female nurse be part of any survey team. The purpose of the survey should be explained in advance to enlist the greatest cooperation in the surveys and in treatment.

Choice of Control Method

There is little latitude for methods other than insecticides. The use of cumbersome steam sterilization or fumigation apparatus has disappeared aside from an occasional institution and is inappropriate for inaccessible areas and for populations the members of which possess only a single garment. Small scale fumigation of clothes may still be utilized and will be referred to later.

Choice of Insecticide and Appropriate Formulation

The most satisfactory formulation for mass disinfection of populations, whether in endemic disease areas or in an emergency situation, is a dusting powder. This is easily shipped, readily stored and easily applied by any type of dusting apparatus from compressed air dusters to hand operated dusters and hand application, though the last is wasteful. Dust formulations leave obvious signs on the clothing and may be a cause of treatment-resistance unless their purpose is first explained.

In view of the spread of insecticide resistance in body louse populations, the choice of the insecticide in a well planned campaign should
be preceded by a survey of the insecticide susceptibility status of the target vector populations. Since a single access to all the population in an affected area is difficult enough, to obviate the necessity of retreatment the insecticide selected must be one which will be effective.

The presence of insecticide resistance in body lice populations may be determined by use of the WHO standard test method. A test kit for use in measuring organochlorine or organophosphorus insecticide susceptibility is described in Annex 4 of the WHO Technical Report Series No. 443 (WHO, 1970) and may be ordered from the Vector Biology and Control Division, WHO, Geneva, Switzerland. Most of the tests described below have been performed utilizing these kits. The latest version of the kit making use of insecticide impregnated papers is suitable for testing head lice susceptibility.

A problem encountered at this stage is who should carry out the tests. Since medical entomologists or other vector control personnel are often few in the countries requiring them the most, it may be necessary for the government concerned to request outside professional assistance and add a factor of increased cost to the survey.

Once the susceptibility of the body louse populations in the area is known, a decision can be made on which insecticide to select. Where populations of body lice are susceptible to DDT, 10 per cent DDT dusting powder is the insecticide of choice.

This compound has very low acute and chronic toxicity to humans and when used as a dusting powder against lice is not likely to contaminate the environment. Where resistance has occurred the following compounds, all formulated as dusting powders, may be used:

- 1% gamma HCH (lindane)
- 1% malathion
- 2% temephos (abate)
- 5% carbaryl
- 1% propoxur

The above have been extensively screened for their effectiveness against body lice and safety to man.

**Whom to Dust**

The quantity of material to be ordered will be determined by the number of people to be dusted and the frequency of dusting. About 30 grams of powder is required per person. Since it can hardly be expected that body louse eradication can be achieved under the conditions of the geographical areas most infested, the campaign should be aimed at those portions of the population most exposed to the threat of disease or those groups where population density is greatest and the spread of lice most frequent. The groups at greatest risk are the contacts of any person.
who has fallen ill with a louse-borne disease, especially his immediate family and visitors. Any patient with typhus or relapsing fever should be dusted upon arrival at a clinic or hospital. Dustings should be periodically performed in schools and prisons in the infested areas. The individuals organizing a campaign can calculate the likely number of individuals to be treated and multiply this by the number of repeated treatments anticipated and add a 10 per cent operational reserve to obtain the total insecticide requirements of ready to use formulation.

Any vector control operation and particularly one that requires treatment of numerous individuals should have professional supervision and a careful follow-up evaluation, including, if the pediculicide is to be used repeatedly, periodic susceptibility tests.

**Louse Control Under Emergency Conditions**

Unlike the preparations that can be made for a dusting campaign in an endemic situation, vector control operations under an emergency situation must be started with great dispatch; little time may be available for advance preparation. This situation can arise with occurrence of an epidemic of typhus or relapsing fever in a population already infested with body lice or, when due to the social upheavals associated with war or natural disaster, a serious increase in body louse infestation with the threat of an epidemic outbreak of disease must be dealt with.

If time allows, insecticide susceptibility tests should be made. However, should an epidemic already be underway, it may be necessary to procure and use insecticides without waiting for the result of such tests. If DDT has been widely used in the affected area, it is probably prudent not to use this compound but to order an alternative. Since the insecticide of choice, or the particular formulation as a dusting powder, must often be obtained from abroad it is best to alert the customs authorities in advance to expedite its rapid clearance. Formulated dusting powder, if obtained from outside of the country, should be sent by the quickest possible method, preferably by air freight. Dusting equipment should be ordered and the various types available are described in the WHO publication "Equipment for Vector Control." Even simple dusting cans with holes punched in one end will suffice in an emergency. When an epidemic of louse-borne disease occurs, all patients, all contacts and all concentrations of people should be dusted rapidly. During the Naples epidemic of typhus in 1943, the USA Typhus Commission set up 40 delousing stations and up to 70,000 people a day were dusted. Conditions preventing washing or changing of clothes encourage the spread of body louse infestations, but, ironically, will provide additional residual protection to dusted people since the dusts will not be removed.

Under certain circumstances fumigants may still be useful and even
necessary. Although generally not applicable to field use, since the infested clothes must be removed from the individual, fumigation to control lice can be particularly useful for institutions or, in emergency, camps. The merits of the different fumigants available have been reviewed by Grothaus and Cole and include HCN, methyl bromide, ethyl formate and dichlorvos. Any fumigation, except dichlorvos, requires well trained personnel to supervise its use. Dichlorvos, while highly effective against adult lice, is not effective against eggs.

Finally, the best way of dealing with an outbreak of louse-borne disease is to prepare for it. In those areas of the world where such outbreaks are not uncommon, continued surveillance of body-louse infestations should be carried out, and samples of lice taken for insecticide-susceptibility tests. Based on these results an appropriate dusting powder and dusters should be stockpiled. Efforts should be made to educate the population on the danger of louse-borne diseases and of the importance of improving hygiene.

Mass Control of Head Lice

From a public health view there is usually little reason to mass de-louse against head lice since they are rarely vectors of disease. However, in populations where the prevalence of infestation is high and longstanding, there are often troublesome secondary infections and a mass control campaign becomes necessary, particularly among school children. While dust formulations can be effective against head lice, they are highly visible and may be resented with immediate efforts to wash them out.

Gerberg has reviewed the compounds currently in use for the control of head lice:

Gamma HCH (lindane)
1% in water dispersible cream-emulsion concentrates
1% in lotion
1% in alcohol diluted 1:5 in water
DDT
10% dusting powder
68% benzyl benzoate, 6% DDT, 12% benzocaine, 14% emulsifier (NBIN), diluted 1:5 with water
Malathion
0.5% in propyl alcohol
Pyrethrum
0.16% pyrethrins, 2% piperonyl butoxide, 5% kerosene, pyrethrins, N-isobutyl undecylenamide, 2-4-dinitroanisole, phenol (MYL)
Lethane
12.5% N-butyl carbitol thiocyanate, 37.5% beta-thiocyanoethyl laurate, 50% refined paraffin.

Of these gamma HCH, malathion and the pyrethrins are the most commonly used.

Where cooperation can be obtained on the part of the parents, shampoos containing gamma HCH or 0.5 per cent malathion can be provided for the infested children and their brothers and sisters. However, such unsupervised use is seldom completely effective since the lice infestations are frequently of little concern to the family. Education of parents and children will be important in controlling head lice though probably not succeed in eliminating them.

Crab Lice

Crab lice control will remain on an individual basis. Dusts containing 10 per cent DDT, 1 per cent gamma HCH or 0.5 per cent malathion when applied twice with an interval of about one week, are effective in controlling crab lice. Shaving pubic hair is unnecessary.

LOUSE RESISTANCE TO INSECTICIDES

Body Lice

Even though the reluctance of an infested individual or of a population to accept treatment may be overcome, an additional problem may be the resistance of the lice to the insecticide. Insecticide resistance is a widespread phenomenon involving over 100 species of insects and other arthropods of public health importance and has appeared in body and head lice populations.

Body louse resistance to insecticides was reported to DDT in Korea in 1950-51, and in Japan. Two surveys were carried out by the WHO on body louse resistance to insecticides between 1953 and 1956, and 1958 to 1963; they showed that high levels of body louse resistance to DDT occurred in Hong Kong, Japan, South Africa, Uganda, Sudan, Afghanistan, Syria, Egypt, Libya, the Gaza Strip, Chile and France. Since that time DDT resistance has been reported from Sierra Leone, Iran, Nigeria, Peru, Yugoslavia, Mexico, Sudan, Burundi, Turkey and Ethiopia, among other countries. Thus, resistance to DDT is wide-spread in most places where DDT dusting powders have been frequently used. If use of this insecticide is contemplated, susceptibility tests must be performed in advance; even where DDT-susceptible populations are present, periodic susceptibility tests must accompany routine dustings.

Gamma HCH (lindane) was a highly effective alternative to DDT; by
the time of the 1953-1956 and 1958-1963 surveys, HCH resistance had appeared in Yugoslavia, Egypt, Syria, Hong Kong, Japan, Nigeria, South Africa, Sudan and Korea. Since that time a steady spread of resistance to gamma HCH has been noted, though it is neither as widespread nor as high as the resistance to DDT, in some countries it would probably exclude its free use. Clark and Cole, by selecting from a strain of lice from Freetown, Sierra Leone with a sevenfold resistance to lindane and a 380-fold resistance to DDT, were able to develop resistance to lindane 8000 times that of a susceptible laboratory strain; there was only a slight increase in tolerance to malathion, pyrethrins and carbaryl in this strain. Cole et al. attempted to select three strains of body lice for resistance to malathion, including one U.S. laboratory strain, one composite strain and one of Korean origin. After 22 to 44 generations of selection there was but a twofold increase in tolerance to malathion though the authors rightfully cautioned that this did not mean that such resistance could not occur in the field. Their "Freetown C" strain developed a fivefold resistance to carbaryl after 25 generations of selection and when body lice of the Freetown C colony were selected at the LC50 level for 71 generations, the increase in resistance to carbaryl increased by 67-fold; when exposed to a 10 per cent carbaryl powder less than 50 per cent of them were killed. As the authors phrased it, "... when the lice were allowed to wallow in the technical powder (99.5% pure) for 24 hours, only 20 per cent were killed. Apparently the Freetown C colony has become practically immune to carbaryl." This strain also developed a 458-fold increase in resistance to DDT at the LC50 level.

With the spread of resistance to the organochlorine insecticides, interest grew rapidly in the testing of possible alternative compounds. Having found malathion highly effective against DDT-resistant body lice in laboratory tests, the compound was tested in sleeve tests on human subjects; 0.5 per cent and 1 per cent malathion powders were compared with 0.2 per cent synergized pyrethrins and 1 per cent lindane; of these 1 per cent malathion was effective for the longest period of time providing a 100 per cent kill for at least 17 days.

In view of the promise of malathion against lice and its known low mammalian toxicity, the effect of a 1 per cent dusting powder was ascertained on volunteers; the clothing of 39 men was dusted five times a week with up to 28 g. of 10 per cent malathion in talcum powder for 5 to 16 weeks. All parameters of the complex tests showed that the compound was safe even at 10 per cent but particularly at the target use concentration of 1 per cent. These toxicologic studies were followed by field trials in Korea and in Egypt; this compound proved superior to 1 per cent lindane in Korea, and to 10 per cent DDT dust in Egypt. Follow-
Louse Resistance to Insecticides

ing these trials, malathion found increasing use against body lice. However, in comparatively little time resistance has now appeared to this compound in Burundi in 1969.21

Experience with other compounds has shown that this may be a very serious development and that resistance to malathion may spread under selection pressure. As Fabrikant et al.10 showed, such selection pressure may come from the use (or misuse) of agricultural pesticides for louse control rather than use of the given compound as a pediculicide. The use of agricultural pesticides for the control of head or body lice can have other serious consequences; Friedman-Mor and Pollak (1972), described 15 cases of poisoning including one death among a group of children in an agricultural area of Israel where various organophosphorus insecticides had been used to control head lice on infested children. A recent report26 to the WHO states that O.P. compounds intended for agricultural use have been widely used against head lice in rural areas of Yemen; an unknown number of people had died. As a result 2 tons of 1 per cent lindane dusting powder was ordered. Evidence of malathion resistance in body lice has been seen in Upper Egypt and Ethiopia and in the latter country may seriously prejudice the possibility of rapid control of louse-borne relapsing fever and typhus.26 While there are several effective, and safe alternative compounds available there can be no room for complacency and the search for still more compounds, preferably in chemical groups unrelated to those to which resistance has developed, must continue.

Head Lice

Though DDT and gamma HCH have been widely used for considerable periods of time against head lice, resistance to the organochlorines has only recently been reported by Maunder19 following field reports of failure of DDT or HCH to control head lice in localities in England where they were formerly effective. The lice tested were resistant to DDT and HCH in the laboratory, but susceptible to malathion, carbaryl and propoxur. Large scale applications of 0.5 per cent malathion lotion provided satisfactory control and has the advantage of being ovicidal unlike DDT or HCH.20 Use of 0.5 per cent malathion in baby oil with added perfumes was found effective against head lice in a trial among several thousand villagers in Israel.18 Recently pyrethrins have been added to this formulation.

DDT resistance has spread to Denmark; following complaints that DDT was no longer controlling head lice, the presence of resistance to that compound was confirmed.9 It is interesting to review the number of requests for information or advice received by the Danish Pest Infestation Laboratory in connection with lice over the last few years.
### Treatment of Resistance in Louse Control

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### Crab Lice

There are no reports of resistance to crab lice. In view of the diversity of pesticides used against this pest the selection pressure for any given compound is probably less than that for head lice and body lice. In view of the increased incidence of *P. pubis* and the subsequent increase in treatment, the future development of insecticide resistance cannot be excluded.

### CONCLUSIONS

Large scale louse control programs face formidable problems especially in developing countries where body louse control is primarily associated with disease control or prevention, as well as in the developed countries where the control of increasing head and pubic lice populations has yet to be achieved. In both situations public awareness of the problem and public cooperation are first steps. In the developing countries where almost all foci of louse-borne diseases remain, the inaccessibility of the foci of disease make the planning and implementation of operational louse control programs difficult and expensive. In virtually all of the developing countries where the control problem is most pressing, a severe shortage of entomologic personnel is a serious impediment to the planning and evaluation of control programs.

Body louse resistance to pesticides has become an operational problem of great magnitude, especially in those countries where pesticides are most needed such as Burundi, Ethiopia and others. While highly effective alternative pediculicides are currently available, their cost is significantly higher than those pesticides (such as DDT or HCH) which they must replace. At present there is little or no alternative to the use of these newer compounds especially in the control of epidemic outbreaks of typhus or relapsing fever. The necessity of extensive, and expensive, toxicologic screening of compounds, not as yet cleared for application to humans, makes it likely that the cost of development of newer com-
pounds will be even greater than previously. It is imperative that mass louse control campaigns be professionally, closely supervised to achieve maximum efficacy in use of the pesticides and that, as much as possible, infested populations be taught to assist the reduction of infestations through personal and collective hygiene.

**NONPROPRIETARY NAMES AND TRADEMARKS OF DRUGS**

Gamma benzene hexachloride—Gamene, Kwell

**REFERENCES**