Insecticides in pediculosis capitis

Ectoparasitosis treatment provides a rare example of the deliberate use of insecticides on human beings. As the bulk of medical insecticide is employed against head lice, scabies lying second, most patients are children. Those prescribing insecticides may wish to understand some of the principles involved.

Insecticide penetration

Insecticides enter insects and ova in accordance with passive physical laws, without active metabolic intervention.¹ The outermost layer of insect cuticles is lipoid and uptake from pediculicidal formulations is controlled by the partition laws.

Insecticide moves from higher concentrations, proportional to saturation, into cuticle waxes, where there is greater saturation deficit. The dose then moving on through the integument per unit area is described by the laws of diffusion, $D = (c_1 - c_2) t k$ where c_1 and c_2 are the insecticide concentrations at the outer and inner boundaries of the integument and $c_1 - c_2$ the concentration gradient driving the diffusion. The dose is equally determined by t , the time of exposure. Twice the exposure doubles the dose. The constant k describes the particular cuticle involved.²

Louse cuticles, having the lowest known lipid content of any insect group,³ are comparatively effective barriers to insecticides, which are always highly lipophilic. Unless k is modified by suitable formulation, then either higher concentrations of insecticides or longer exposure times must be employed against lice than against other insects, and these will equally be experienced by patients.

Concentration and time are all important as regards the lice, the actual quantity of insecticide present being irrelevant. As regards human toxicity, however, it is the total quantity present which is vitally important. If there isn't enough insecticide there, then the patient cannot be harmed. The aim of pediculicide formulation is to maximise the dose acquired by the insects while minimising the amount of insecticide employed.

Formulation types

Formulators achieve these objectives in various ways.

(1) PHASE SEPARATION LOTIONS

Small quantities of insecticide are dissolved in small

volumes of lipid, typically forming solutions of about 20%. Adjuvants may be added to reduce the solubility and so raise the percentage saturation, ideally to just below complete saturation. This solution is then emulsified into a larger volume of water, to which stabilisers and perfumes may be added. The resulting water based emulsion may have an overall concentration of no more than 0.5%. On the head it separates into its constituent phases. The lice and eggs become coated with a thin lipid film containing 20% insecticide, but at perhaps 70% saturation, while the aqueous phase merely wets the hair.

A typical two hour application may subject lice to 8000 arbitrary units of dose, although no more than 100 mg of insecticide may be present on the head.⁴

(2) EVAPORATING LOTIONS

A small quantity of insecticide is dissolved in a large volume of isopropanol, to which up to 40% of water has been added to lower the solubility and so raise percentage saturation. When on the head, spirit and water evaporate together, being an approximate constant boiling mixture. The insecticide concentrates to a fine film coating lice, eggs, and hair. High effective concentrations are achieved using low quantities of insecticide and initial overall concentrations of no more than 0.5%.

(3) INSECTICIDAL CONDITIONING SHAMPOO

Shampoos are immediately diluted with much water. This is not necessarily bad because if the insecticide is very soluble in the organic materials present the water greatly raises the percentage saturation in the final mixture. Many an insecticidal shampoo only kills lice when diluted.

When insecticides were first incorporated into detergent shampoos the formulations had only about three minutes in which to act and were poorly effective. Even a 1% shampoo at 80% of saturation can only amount to 240 arbitrary units of dose over three minutes.

Modern good quality shampoos now not only remove dirty oils, but replace them with conditioning lipids. If these now contain the insecticides a substantive effect is possible, enhancing pediculicidal activity, but still the short contact time is a problem which needs circumvention.

Limits to insecticide efficacy

In large populations of insects tolerances to insecti-

cides are normally distributed about a mean, so that dose/response plots produce sigmoid curves, the upper ends of which are effectively asymptotic, approaching but never meeting the 100% mortality level. There is in theory no dose which just kills all of an infinitely large population.

In practice, even doses which give 99% mortality must be multiplied many times to give 99.9%. Manufacturers' claims for 100% mortalities must be viewed with suspicion.

Insecticides act on nervous systems, which young insect eggs do not yet possess. Mature eggs have a fully formed louse, with its own cuticle, still within the intact eggshell. Consequently both new laid and mature eggs are exceedingly difficult to kill, especially with short contact times. Ovicidal action is invariably unsatisfactory with single applications of insecticidal shampoo. In practice this need not matter, nor does it usually help to raise the ovicidal effect of the shampoo, for this is virtually impossible adequately to do, and quite unnecessary providing rational treatment strategies are used to turn the insects' own biology against themselves.

Treatment regimes for shampoo

In nature head louse eggs hatch in six to eight days and the nymphs require a further 10 to 12 days before they can themselves lay fresh eggs.⁵

Clearly, then, shampoos should be used as a course of treatment, preferably using monitored unit applications, say twice a week for two weeks. The first application should kill all walking stages but only some eggs. The second kills any newly

hatched nymphs and a further proportion of eggs. By the third application all eggs must be hatched or dead, any surviving nymphs are killed and there are no adults left to lay new eggs. A fourth application allows for human error.

When used as a course of treatment, any insecticidal shampoo with adequate action against nymphs and adults will be fully effective. Naturally, medical entomologists have always preferred lotions, where a total cure can often be achieved in one step, but the general public will need much education before modifying their preference for shampoo.

Insecticidal shampoos, however, should still be regarded as medicines and prescribed for a defined course of treatment with a firm termination: the indefinite use of powerful insecticides is highly undesirable.

References

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