



# *Pediculosis and Resistance: The Perennial Problem*

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**D**oes resistance really exist among human ectoparasites? Do treatments for pediculosis become less effective over the years? Do the mites or lice actually develop resistance to the insecticides created by humans to do away with these parasitic arthropods?

For the past three decades, we have carefully followed the literature and listened to discussions about resistance and human lice.<sup>1,2</sup> Periodically, the question of resistance surfaces, but it is never satisfactorily answered nor is it sufficiently dismissed.<sup>3,4,5,6,7</sup>

## Definitions

A major problem in the discussion involves the definitions. While denotations should be appropriate to set apart the terms involved, many times, connotations of selected words become intermingled with the denotations.<sup>1–30</sup>

**CURE** absence of live lice and/or viable nits when evaluated at 14 days.

**INSECTICIDE OR PEDICULICIDE** a chemical that kills the insect. While the mechanism of action is often not known, respiratory paralysis is usually responsible for death.

**LOUSE** the adult form of *Pediculus capitis*, *P. corporis*, and *Pthirus pubis*, the three members of the Anoplura order that infest humans.<sup>8</sup>

**NIT** the encapsulated egg of a louse. (Some observers consider only the empty shell as a nit.) The viable nit is a small, whitish to semitranslucent object attached to the hair. It fluoresces under Wood's light. The dead nit or hatched nit, which is also attached to the hair, is opaque and gray. Newly laid eggs take 9–12 days to hatch.

**NIT-FREE** the patient must not have even one nit attached to a hair on the scalp whether or not the nit is dead. The nodule should be differentiated from hair casts (muffs), debris, and hair shaft abnormalities.

**NPA** National Pediculosis Association founded in 1983 as Mothers Against Lice. An organization that fosters a nit-free environment.

**NYMPH** a developing louse. There are three instars of development, each of which is completed in 3 days. The maximum lifespan from hatching to death is approximately 30 days.<sup>8</sup>

**OVICIDAL** absence of nymphs at 7–10 days: can also be determined by *in vitro* studies.

**OVICIDAL FAILURE** presence of first and second instar nymphs 1 week after treatment.

**RECURRENCE** presence of newly hatched lice (first and second instar nymphs) 7–10 days after treatment.<sup>10</sup>

**REINFESTATION** presence of live lice in all stages of development and viable nits in children previously considered cured.<sup>9</sup>

**RESIDUAL EFFECT** retention of pediculicide on the hair and scalp after washing. It kills emerging nymphs and prevents reinfestation for a limited time.

**RESISTANCE** abnormal strains of the same species that acquire immunity to a given insecticide through selective breeding. This immunity is acquired through exposure to an insecticide, which kills susceptible insects and leaves the hardier survivors to reproduce.<sup>11</sup> Presence of live lice 24 hours after treatment.<sup>10</sup>

**TREATMENT FAILURE** the insecticide was applied in the appropriate manner, but live lice and viable nits are present 24 hours after treatment.

## Treatment

Effective treatment<sup>29</sup> can be achieved if the pediculicide is applied carefully and of sufficient quantity on two occasions 1 week apart. A nit comb should be used during that interval, and the patient should be checked for surviving lice and nymphs between treatments and for the following week.<sup>28</sup>

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## Pediculicides

**DDT** an organochlorine compound. It has been used as a dusting powder and lotion.

**LINDANE** an organochlorine compound used as a 1% shampoo or cream. Lindane has low to medium ovicidal activity and no residual effect.<sup>30</sup> The shampoo is applied undiluted to dry hair. After 5 minutes water is added, creating a lather, and the hair is rinsed. A second application is not recommended because of possible neurological damage<sup>31</sup> that may be caused by excessive exposure to the medication. Blood levels increase with repeated use and accumulate in the body.<sup>32</sup> The FDA recommended labeling the product that encourages the use of lindane only for patients who have either failed to respond to adequate doses or are intolerant of other approved therapies.

**PYRETHRIN** a derivative of the *Chrysanthemum cinerariaefolium* (pyrethrum) flower heads. It is usually combined (synergized) with piperonyl butoxide (Butacide). The latter compound has insecticidal activity and antioxidant properties, which prevent or decrease the development of resistance. It prevents oxidative breakdown of pyrethrins by the insect's detoxification system.<sup>7</sup> The combination is available as a gel, lotion, and shampoo. Commercial products in the USA include RID shampoo: R&C shampoo; A200 pyrinat shampoo, liquid and gel; Triple-X; Para-nit; Pronto; Paratrol; Clear Lice System; Basc, and NoLice. Synergized pyrethrins have low to medium ovicidal activity and no residual effect.<sup>30</sup> These products are applied to dry hair for 10 minutes and then rinsed off with water. Patients with allergy to ragweed or turpentine should avoid their use.<sup>33</sup> A second application is recommended at 7-10 days. Nit removal is necessary.

**PYRETHROID** a synthetic pyrethrin. It is available as 1% permethrin creme rinse (NIX) and as 5% permethrin cream (Elimite). Pyrethroids have high ovicidal activity and residual activity for 2-3 weeks.<sup>30</sup> Permethrin is applied to dry hair after shampooing with an anionic shampoo without a conditioner (Prell concentrate). Dry the hair thoroughly with a towel or hair dryer. Then saturate the hair with permethrin creme rinse and massage into scalp, especially behind the ears and the base of the neck. Rinse off after 10-20 minutes. Do not use a regular shampoo again for 24 hours. Use a nit comb and repeat after 7 days.<sup>30</sup>

**MALATHION** an organophosphate compound, an irreversible cholinesterase inhibitor. It is used as a 0.5% lotion (Ovide lotion). Malathion has moderate to high ovicidal activity and some residual activity.<sup>30</sup> This is applied to dry hair in an amount to thoroughly wet the hair and scalp. Wash hands after applying. Allow hair to air dry, and do not use a towel or hair dryer. A

regular shampoo can be used after 8-12 hours. Use a nit comb and repeat application after 7-10 days.<sup>30</sup> Malathion has an objectional odor due to release of sulfhydryl compounds through hydrolysis.<sup>7</sup>

**NIT REMOVAL** complete nit removal plays an essential role in the management of infestation. Because no pediculicide is 100% ovicidal, grooming and nit removal in the period between treatments are essential. Combs that are sold with the pediculicides are often made of plastic and are not as good as a metal comb. The teeth of a plastic comb often bend and break, especially when used on coarse, thick hair. A metal comb, LiceMeister, can be purchased through the NPA or through the Internet. Applying a conditioner, a creme rinse, a detangler, or a light oil can facilitate combing the hair. The cement protein that binds the nit to the hair can be loosened by wetting the hair with water or by application of a mixture of 50% distilled white vinegar and 50% water or by use of a product called Step 2, which contains 8% formic acid. The latter product is sold with a metal nit comb.<sup>34</sup>

## Education

Upon discovery of an infestation, parents should notify the school and the school in turn should notify the other parents. Teachers, parents, and the school nurse should be instructed in screening techniques, about the available parasitocides, methods of controlling fomites, and how to prevent reinfestation.

## Fomite and Environmental Control

Sharing combs, brushes, washcloths, towels, and headgear should be avoided. While at school, clothing should be stored under the desk or seat<sup>33</sup> or in a large backpack or plastic bag and not on closely set pegs or shelves. Combs and brushes may be coated with the parasiticide for 15 minutes and then washed in hot water. Towels, wash cloths, headgear, clothes, and bed linens should be washed in hot water and dried on the hot cycle. Nonwashable items should be dry cleaned or sealed in a plastic bag and stored in a warm place for 2 weeks.<sup>30</sup> Rugs, upholstered furniture, mattresses, and car seats should be vacuumed to remove lice and hair with attached nits that might have been shed.

## Contact Control

All family members and close contacts over the preceding month should be examined for evidence of infestation.<sup>31</sup> Screening with a nit comb is more effective than when done by hand.<sup>30</sup> It is often difficult to detect an early infestation because these patients are usually asymptomatic, and lice and nits are hard to find. The majority of infestations go undetected for several weeks after they begin. When in doubt, it is better to treat all

close contacts that may be carriers than to treat the same child repeatedly.<sup>30</sup>

### Ancillary Measures

Treatment of the associated skin irritation and infection with topical steroids and systemic antibiotics is an important part of management.

### Reasons for Treatment Failure

Most treatment failure can be attributed to causes other than resistance.<sup>28</sup> These include poor compliance or improper use of the antilice product, lack of nit removal, new exposure to lice, and use of an out-of-date preparation. Applying the insecticide to wet hair reduces its activity. When immersed in water, lice grasp hairs reflexly and close their spiracles, or breathing apparatus, thereby reducing penetration of the pediculicide into the louse.<sup>10</sup> Shampoos, creme rinses, and lotions should therefore be applied to dry hair for most effective use. Applying the antilice medication to hair that has been wet with water also dilutes the insecticide, decreasing its concentration. Because of the short contact time and the dilution factor that occurs when water is added to a shampoo preparation, insufficient amount of concentrated insecticide is present for too short a time to kill lice and viable nits, and in many instances, both survive.<sup>28</sup> For this reason, although shampoos are convenient, they are considered less ovicidal<sup>35</sup> and have been blamed for fostering the survival of the head louse.<sup>10</sup> Using an insufficient amount of the pediculicide can also result in treatment failure. This is especially common when using lotion preparations. Thick and long hair requires more pediculicide to completely wet the hair. A sufficient amount of lotion should be used to thoroughly wet all of the hair, especially behind the ears and at the nape of the neck. Often, these sites of high prevalence are never exposed to the insecticide. Avoid using a shampoo with a built-in conditioner before applying a pediculicide. The conditioner in the shampoo can coat the hair, interfering with bonding of the pediculicide to the hair and scalp.<sup>30</sup> When bonding is prevented, the residual effect of the antilouse preparation is diminished, allowing emerging nymphs to survive and also permitting reinfestation to occur. Because there are no pediculicides that can kill all viable nits, lack of nit removal and retreatment at 7 days will result in treatment failure. Reinfestation is always possible but depends on the presence of untreated close contacts who may be carriers and the duration of the residual effect on the treated hair. Finally, pyrethrins are unstable when exposed to heat and light: therefore, old products may be ineffective.

### Resistance—Scope of the Problem

Shortly after the introduction of DDT in the 1940s, resistance to body lice appeared in Korea at the onset of the conflict in 1950. By the mid 1950s, at least 37 countries had reported DDT resistance of *P. corporis*.<sup>1</sup> Subsequently, reports appeared in the 1970s and 1980s, suggesting resistance of both head lice and pubic lice.<sup>1,4,5,11,12</sup> Even pseudo-resistance was reported.<sup>6</sup>

Within the past few years, there has been a resurgence of interest in the subject because of treatment failure after use of currently available pediculicides. Resistance to lindane in head lice was reported in the United Kingdom in 1971<sup>13</sup> and the Netherlands in 1978.<sup>14</sup> Treatment failure was reported in Panama in 1986,<sup>15</sup> in Arizona in 1986,<sup>16</sup> and in Mexico in 1987.<sup>17</sup>

Resistance of body and head lice to synergized pyrethrins was reported in 1961<sup>18</sup> and of head lice in the Netherlands in 1979.<sup>19</sup> A study reported in 1995 concluded that the natural pyrethrins are not sufficiently effective to justify their use.<sup>20</sup>

Resistance to pyrethroids was first reported in Tasmania in 1990.<sup>5</sup> Since then, resistance has been reported in France in 1994,<sup>21</sup> the Czech Republic in 1995,<sup>22</sup> Israel in 1995,<sup>23</sup> Britain in 1995,<sup>24</sup> and Argentina in 1998.<sup>25</sup> Some studies showed cross-resistance to other members of the pyrethroid family of drugs.<sup>25</sup>

Clinical evidence of resistance to malathion appeared in England in 1972,<sup>26</sup> Tasmania in 1990,<sup>5</sup> France in 1995,<sup>27</sup> and again in southern England in 1995.<sup>28</sup>

Clinical treatment failures in many instances were correlated with results of laboratory tests on pediculicides. There was also a relationship between previous extensive use of the pediculicide and treatment failure.<sup>15</sup>

### Reasons for Louse Resistance

Resistance both clinical (treatment failure) and in the laboratory has been reported from many parts of the world to all commonly used pediculicides. This is not surprising, in view of the adaptability of insects.<sup>21</sup> The evolution of genetically selected tolerance or resistance when an insect is repeatedly exposed to nonkilling (sublethal) concentrations of a pediculicide is inevitable<sup>36</sup> and will result in the emergence of a population of insects that are immune to the product.<sup>21</sup> This can be accomplished, theoretically, by use of products with residual activity.<sup>20</sup> While residual activity may supplement a poorly ovicidal product and temporarily help prevent infestation, as the level of pesticide wanes, sublethal concentrations prevail on the hair and scalp.<sup>20</sup> If lice are present, they are usually nymphs, unless there had been a reinfestation. Resistance develops more easily when nymphs rather than adults are exposed, possibly because nymphs are exposed for a longer time.<sup>1</sup>

Exposing lice to nonkilling concentrations can also occur because of use of inadequate quantities of the pediculicide, by dilution of the product when applied to wet hair, or by using a shampoo formulation.<sup>30</sup> Shampoos often result in dilution and short contact time. Resistance is always due to partial treatment failure.<sup>37</sup>

Clinical and laboratory observations have demonstrated that repeated and prolonged use of the pediculicide on a louse population is likely to select out resistant lice.<sup>21</sup> Previous extensive use of lindane-containing products is related to lindane resistance.<sup>30</sup> Exclusive use of pyrethroids in Israel resulted in a lack of efficacy of permethrin.<sup>23</sup> Head lice in the United States are less susceptible to permethrin than are lice in an area where the product was never used.<sup>38</sup>

Cross-resistance to other insecticides with a similar chemical structure or mode of action may also occur.<sup>30</sup> Some believe that the previous use of DDT in addition to a pyrethroid with minimal residual activity and malathion set the stage for the rapid development of resistance to permethrin in Israel.<sup>23</sup> DDT, lindane, and pyrethroids affect the sodium channels in nerve cell membranes, thus affecting repolarization, while malathion affects acetylcholinesterase in nerve synapses. Detoxification enzymes that prevent the insecticide from reaching the site of action cause resistance of some lice. Resistance to most insecticides is produced by the oxidase mechanism (mixed function oxidase), while the esterase mechanism is often associated with resistance to malathion. Lice therefore can become resistant by one or more mechanisms.<sup>30,39</sup>

### Strategies for Control of Suspected Louse Resistance

During the past few years, anecdotal reports have surfaced of suspected head lice resistance (treatment failures) in some communities in the United States. This resistance is to all commonly used pediculicides, including synergized pyrethrins, 1% permethrin, and even 5% permethrin cream. At the present time, this resistance to recommended drugs remains poorly defined<sup>38</sup> due to insufficient data.<sup>40</sup> Because exposure to a pediculicide may be different, reports of resistance in one community may not be valid in another.<sup>41</sup> Therefore, the relatively safe over-the-counter pediculicides remain the products of choice for newly recognized infestations.<sup>38</sup>

Parents should use the standard preparation as initial treatment, carefully following the manufacturer's instructions. If lice remain alive 24 hours after treatment, they are probably resistant and further treatment with the same or related agent will not be effective, and will only expose the child to more insecticide. The parent should then switch to a product that contains a

different chemical and make every effort to follow the package instructions for use.

Overkill, using the product according to instructions, is the best way to avoid development of the population of head lice that includes individual insects with varying gradations of resistance.<sup>42</sup> When choosing this alternative product, it should be borne in mind that lotions remain undiluted after application and deliver a higher concentration of the pediculicide to the lice and viable nits for a longer period of time.<sup>43</sup> Furthermore, alcoholic vehicles penetrate the aeropyles (breathing pores on the operculum) of nits and the louse spiracles better than aqueous vehicles.<sup>10</sup> Finally, before deciding that the lice are resistant, reinfestation should be excluded.

The best choice of pediculicide will depend on local resistance patterns:

1. Permethrin cream 5% (Elimite)—apply to dry hair for 10 minutes<sup>33</sup> or leave on overnight with a shower cap.<sup>30</sup>
2. Apply a pediculicide with a different chemical structure, such as lindane or malathion (resistance to malathion has not been reported in the United States in recent years).
3. Physical modalities such as mechanical louse and nit removal.
4. Apply an occlusive agent to asphyxiate the lice. There are several choices but no controlled studies. Vaseline petroleum jelly, hair pomade, olive oil, mayonnaise, Crisco vegetable shortening, mineral oil, or essential oils purchased from health food stores have been used. Vaseline petroleum jelly is applied overnight under a shower cap. This requires repeated overnight treatments followed by combing.<sup>30</sup> The Vaseline is difficult to wash out. To remove the Vaseline, apply "Goop," a mechanic's hand cleaner, all over the scalp. Rinse after 10 minutes. Next apply "Gojo," an orange pumice hand cleaner, to the hair when dry. Leave on for a few minutes and then rinse off. This is followed by use of a regular shampoo.<sup>44</sup>
5. HairClean 1-2-3 consists of anise, ylang-ylang, coconut oils, and isopropyl alcohol. This product is available in health food stores. It is applied to dry hair and shampooed off after 15 minutes. The treatment is repeated 1 week later.<sup>30</sup>
6. Cotrimoxazole (sulfamethoxazole-trimethoprim) (Septra, Bactrim). Antibiotic present in the blood meal kills the louse's symbiotic bacteria necessary for survival. This medication is administered orally in a therapeutic dose for 3 days followed by a second course after 1 week.<sup>29</sup>
7. Ivermectin, a macrocyclic lactone (Mectizan), is an antihelminthic agent. Ivermectin is given orally in a dose of 200 µg/kg. Some children will require a

second dose on the next day.<sup>30</sup> Another recommendation is to give the second dose 7–10 days later, especially if nit removal is incomplete.<sup>33</sup> Ivermectin is not ovicidal.<sup>45</sup>

8. Lice Guard Spray to prevent infestation and reinfestation. No studies have been done to prove its effectiveness.

## Conclusions

Useful terms related to the head louse and its treatment are defined. Successful treatment depends on using the pediculicide according to the manufacturer's instructions in sufficient quantity to wet all the hair, use of a nit comb, followed by repeated observation. Reasons for treatment failure are discussed. Resistance to pediculicides is worldwide; possible reasons for this are discussed. Finally, strategies for management of suspected louse resistance are outlined.

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The familiar Jefferson nickel was first introduced in 1938 with a composition of 75% copper and 25% nickel. Felix Schlag an independent artist won a national contest, which had over 390 entrants, in designing the new 1938 nickel.<sup>1</sup> During the World War II nickel and copper were strategic metals needed in the war effort. Nickel for stainless steel and as a metal hardener, and copper for ammunition casings. The mint removed all the nickel from the coin and decreased the copper content and replaced it with silver and manganese. During the war effort (1942–1945) the nickel had a composition of 56% copper, 35% silver, and 9% manganese. A dimethylglyoxime test would show no trace of nickel in these wartime nickels. A large P, D or S representing the Philadelphia, Denver and San Fran-

cisco mints was placed on the coin reverse over Monticello so that the coins could be recognized.

#### LEGEND:

Post WW II five cent coin on left tests positive for nickel metal while the wartime five cent coin is negative for nickel metal. The large “P” stands for Philadelphia, where the coin was minted.

From the collection of Raymond T. Kuwahara, MD, Memphis, TN.

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