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Head lice.

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Summary The history of head lice strictly interlaces with the millionaire history of the human, supporting the evolutionist theory. In a disease characterized by a so long history, two new things emerge. The introduction on the market at the end of '90ies of a product consisting of coconut extract, anise and ylang ylang oil revolutionized the market of pediculicides, so that from that event onwards no new products with neurotoxic activity were marketed, but only various versions of pediculicides with physical activity. The other novelty was the advent of entodermoscopy, a new science that allowed dermatologists to study *in vivo* the anatomy, physiology and biology of head lice, helping them in the difficult task of establishing the vitality of a colony of head lice.

Key words Physical pediculicide, natural oils, dermoscopy.

The diseases caused by lice in the humans are pediculosis capitis, which is really the most frequent, pediculosis corporis, which can be seen in people who do not wash and do not change their clothes for various reasons, and finally pediculosis of the pubes. The latter affects the eyelids in the prepubertal period.

Pediculosis corporis is caused by Pediculus humanus corporis, very similar to head louse, but used to live in the clothes, to move to the skin of the host only when it has to eat its blood meal, whereas pediculosis of the pubes and eyelids are caused by Phthirus pubis.

1.0 Historical note

The history of the louse strictly interlaces with that one of the humans and their ancestors, supporting the evolutionist theory of the origin of the human from other mammalians (36). The morphological and molecular data indicate that the louse of the baboon (Pedicinus hamadrias) originated about 25 million of years ago from a progenitor louse of a rodent. Moreover, these data indicate that from a common intermediate progenitor 5.6 millions of years ago originated Pediculus humanus and Pediculus schaeffi of the chimpanzee. Interestingly, these data coincide with the separation of the cercopithecoids from primates Hominidae, occurred 20-25 millions of years ago and with the subsequent separation of the Hominidae from chimpanzee, occurred 5.5 millions of years ago (47).

The oldest texts, which arrived to us, already talk about lice, particularly in the chapter 8, 17 of the Exodus. In the latter, Moses, following a divine advice, tells Aaron to grasp the stick and to strike it on the dust of the ground, changing this way in lice -but according to another version in gnats- the dust of the ground through Egypt.

Meinking and Taplin (28) summarized exaustively the ancient traditions associated with head lice, underlining that in the past head lice were considered as a natural presence of the domestic environment.

This is why they were used as a token of one's love or as a sign of respect toward the sovereign or even as a food.

Obviously, the relationship between human and head lice were not always idyllic and for thousands years the men tried everything possible to get rid of this disagreeable host. However, the latter was so resistant and adaptable to neutralize all their efforts.

2.0 Anatomy and physiology

Pediculosis capitis is caused by Pediculus humanus capitis (phylum: Arthropoda, class: insecta, order: Anoplura, family: Pediculidae, genus: Pediculus, species: Pediculus humanus). Head louse, which is visible to the naked eye, is long a little less than 3 mm (Fig. 1), the male being 0.3-0.4 less long than the female.

Its gray-brownish color is related to the color of hair of the host, thus clearer in subjects with

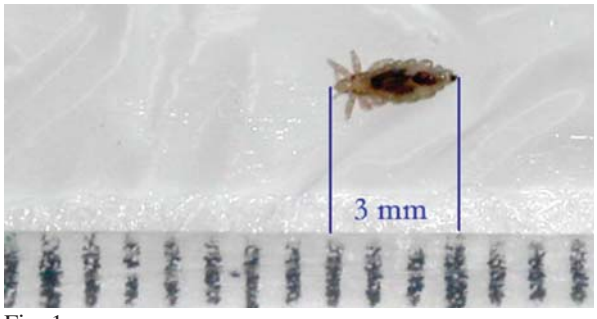

Fig. 1

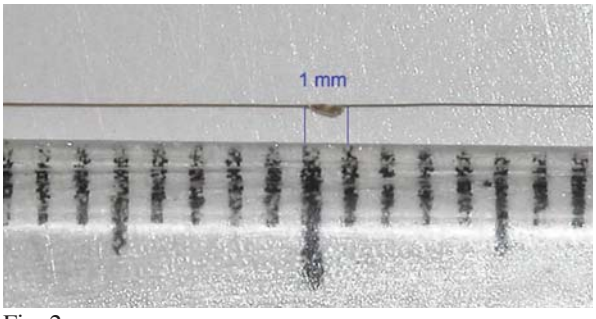

Fig. 2

Fig. 1, 2: The head louse is long about 3 mm (Fig. 1), whereas the length of the nit (Fig. 2) is about 1 mm.

Fig. 3

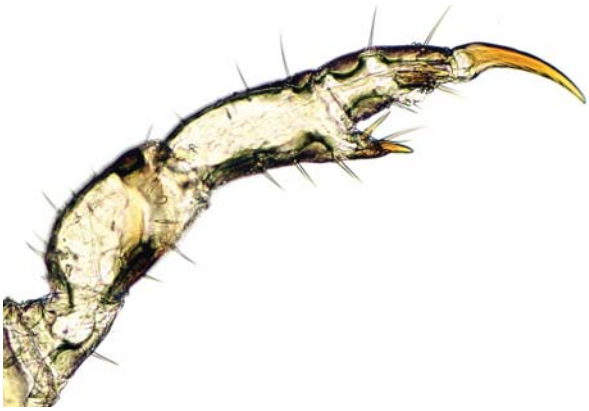

Fig. 4

Fig. 3, 4: Head of Pediculus capitis (Fig. 3). You can well see the antennae, that are divided into 5 segments. In Fig. 4 a leg with its various segments and the terminal hook.

clear phototype (27). In the adult stage the head louse has not wings. Its body, flattened in dorsal-ventral direction, consists of the head and nine segments. The first two segments are fused to form the thorax, whereas the other seven form the abdomen. Its integument is adorned by a net of thickenings and crests and covered by thin cilia, spines and gross bristles.

2.1 Gastrointestinal apparatus

On the head, which is narrower of the thorax and abdomen, there are two antennae (Fig. 3), two eyes located behind the antennae and a buccal apparatus. The antenna consists of five segments -three in the neanides- supplied with sensory hairs. The buccal apparatus, of stinging-sucking type, thus able to pierce the skin of the host and to suck his/her blood, contains a proboscis. The latter is a tubular structure supplied with teeth, that becomes everted when the louse must feed and invaginated when it is not useful, thanks to the action of labial and mandibular muscles. During its blood meal, the louse presses its buccal apparatus against the skin of the host and digs its proboscis into it, so that the curved teeth of the proboscis anchor its head to the skin. The proboscis leads in a large vestibular cavity that continues dorsally with the pharynx and ventrally with the trophic sac. The latter is a cavity containing three stilettos as follows: one dorsal that represents the sucking channel of the blood and consists of two hollow opposed laminae, one ventral supplied with solid teeth and curved as a gutter, that corresponds to the lower lip, and finally one intermediate or hypopharynx, that contains the channel of discharge of the saliva. The latter, which contains anesthetic and anticoagulant substances (9), is secreted by two pairs of salivary glands located in the thoracic cavity. The saliva has an irritant (11) and sensitizing (28) capability. Not only the adult louse but even the neanide, just emerged from the egg, takes on the skin of the host its first blood meal, that changes the color of its body (Fig. 49), before transparent, dying it red.

The blood of the host is the only source of food for the louse. According to a common belief, this monotonous meal is digested and assimilated thanks to the presence of symbiont bacteria in the intestine of the louse. It is also believed that the pediculicide activity of the antibiotics and particularly of trimethoprim-cotrimoxazole is due to the distruction of the symbiont bacteria. The latter hypothesis is probably true, although for the louse, unlike other insecta, the contribution of the intestinal symbiont bacteria is of no value.

The symbionts of the louse are Gram positive bacteria. They stay in the mycetoma, a structure

with 12-16 concamerations, that originates during the fetal life in the intestine. Later on, before neanide emerges from the nit, mycetoma, although attached to the stomach, does not communicate with the intestine.

When the sexual dimorphism becomes evident, a little before the third molt, mycetoma develops fully in the female, whereas in the male it undergoes degeneration. Before laying the egg, the female injects some symbionts into the proximal extremity of the egg, namely in the pole opposite to the operculum. In absence of mycetoma the young lice live a few days and females remain sterile. During the embryonic development the aggregate of symbionts migrates towards the middle of the embryo giving raise to mycetoma.

Taking into account these data, some Authors (28) hypothesize that symbiont bacteria are implicated in the laying of the eggs, maybe in the production of the glue that cements the egg to the hair. On the other hand, at least in lice, they do not play any role in the process of assimilation of their blood meal. This hypothesis does not contrast with the regression of the infestation due to antibiotic treatment.

2.2 Locomotor apparatus

The thoracic plate, deriving from the fusion of the first two segments, is supplied with three pair of segmented legs (Fig. 4), consisting of coxa, trochanter, femur, tibia and tarsus. The latter ends with hooks able to stably grasp to the hair of the host.

The head louse is able to move rather quickly, canning cover till 23 cm in a minute (28), but usually remains always near the scalp, the calor of which is necessary for its survival. This is why laying of the eggs always occurs very close to the proximal extremity of the hair, unless favorable environmental conditions do exist, as an external temperature higher than 30°C.

2.3 Respiratory apparatus

Lice have a well developed respiratory apparatus essentially consisting of tracheas, that are branched tubes deriving from ectodermal invaginations. The latter end externally with numerous openings, particularly seven openings for each side of the body, the first one between the

Fig. 5

Fig. 6

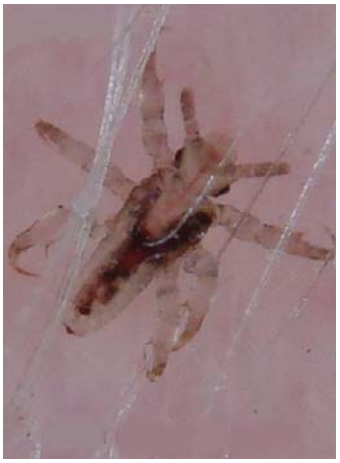

Fig. 7

Fig. 5, 6, 7: Female (Fig. 5), male (Fig. 6) and neanide (Fig. 7) of the head louse. You can see the larger size of the female, its respiratory openings and two eggs. In Fig. 7 the blood meal of the neanide till defecation.

first and second leg level with the thorax, the other 6 on the abdominal segments, except for the last. The respiratory openings or spiracles are small holes (Fig. 5), often supplied with valves and followed by a cavity covered by hairs useful to prevent the entry of dust and foreign particles (4). The cavity consists of an alveolar structure, that enlarges the surface useful for air and humidity exchange (28).

2.4 Reproductive apparatus

Lice as well as almost all insecta are gonochoric and are characterized by sexual dimorphism. Males are usually smaller than females and have a characteristic pigmentation of the abdomen. The latter in females, besides containing the eggs, is uniformly pigmented, whereas in males it is characterized by brownish transversal bands. The female is larger and longer than male. In the male (Fig. 6) the abdomen ends with a roundish protuberance and with a single orifice for the penis and anus, whereas in the female the terminal part of the abdomen is bilobate (Fig. 5) due to the presence of gonopodes. The latter are structures that allow its adhesion to the hair, during the egg-laying.

Moreover, the female has large accessory glands secreting a glue substance that guarantees the perfect adhesion of the egg on the hair (4). The cement is discharged from the genitalia of the female before the egg and is necessary to cement the latter to the hair. Nobody knows solvents able to melt this cement, whose prevalently proteic composition is very similar to the amino acid composition of the shaft of the hair (9).

Usually the egg is laid less then three millimeters from the scalp. However, when the temperature is about 30°C, many eggs can be laid on the same hair even several centimeters far from the scalp. The egg has an operculum, namely a multilobate cap, always facing the distal extremity of the hair. Each lobe of the operculum has a central hole. The latter allows the air and water vapor to pass through. The egg hatches 7-8 days after laying and a neanide, namely the young stage of the louse, goes out. The neanide is very similar to the adult louse, but smaller and pale.

The hatching process of the egg is unique. The neanide, using the teeth of its proboscis, makes a roundish hole in the operculum, sucks the external air and expels it from the caudal pole (28) to pass through the hole more easily. The neanide needs a few transformations before getting adult, namely it undergoes no radical metamorphosis (metabolia). The life of the neanide is characterized by three periods, each one lasting three days till the final molt, from which originates the adult louse. The latter in a few days reaches the sexual maturity and starts a new life cycle (4). The molt is a necessary process due to the stiff integument -exuvia (Fig. 56)-, that prevents the natural growing of the neanide and therefore is discharged during every molt.

3.0 Epidemiology of pediculosis

The prevalence of the infestation caused by head lice cannot be exactly assessed because even in the countries where the notification of infestation is compulsory, the cases reported are always a minority as compared with those not reported. This is due to the prejudices related to the infestation. The latter is still today really considered by many people as expression of poverty and scarce hygiene as well as scabies and other infestations.

About five million children between 6 and 12 years are every year infested by head lice (17). In Italy the case reported every year range between 3,000 and 5,000 (2). Unlike pediculus corporis, the head louse does not differentiate rich from poor people and affects without distinction developed and developing countries. In the latter the percentage of infested subjects can reach 90% (17), but only because the inhabitants of these countries have to face problems more important than head lice.

On the other hand, in the United States head lice are less frequent in Afro-American population. In this case, however, the social and economic conditions do not play a significant role. In this case the difficulty of head louse to grasp the

hair with oval section of Afro-Americans is probably more important (25). In many developed countries pediculosis capitis increased in the last two decades, in spite of the improved hygienic conditions and all the treatment carried out (6, 23).

Head lice can affect any age. However, most cases occur among children of the nursery and primary school, probably due to the more frequent head-head contact at this age. In Italy 70% of the reported cases is aged less than 15 years (2).

The relationship between sex prevalence and head lice is controversial. Females do not prevail in all the series of cases (27). For instance males prevail among the cases reported in Italy (2).

In our series of 426 cases the female/male ratio ranges in the various years between 3/1 and 10/1. People supporting the greater prevalence of head lice in females, attribute this difference to the greater frequency of the head-head contact and to the more frequent predisposition of females to exchange combs and brushes, whereas the usually longer hair does not play a significant role.

4.0 Modalities of contagion

The contagiousness of pediculosis capitis is not so high as that one of some infectious diseases. The infestation is transmitted only by an adult fertilized female or more individuals of different sex, that pass from the head of an infested host to a very close head of another host. This happens only when the hair of two different subjects, one of whom infested by head lice, are in physical contact. There is not other possible manner of contagion, because the head louse does not jump and, being devoid of wings, does not fly.

The possibility of contagion through combs, brushes, hair bands and clothes is scarce, because the head louse does not survive more than twenty hours, when removed from the scalp of the host. On the other hand, when the temperature is about 30°C, an indirect contagion gets more possible. The initial contagion usually occurs at school, but other individuals can be infested in the domestic environment, mainly in conditions of promiscuity.

5.0 Symptoms and signs

An active pediculosis capitis can be silent for several days, not giving any sign, without even pruritus, mainly in subjects without any previous contact with saliva and feces of louse. This is why a new case of pediculosis in a group should induce to examine the other subjects of the group, even in absence of symptoms. On the other hand, in case of second infestation, the patient presents more precociously pruritus, probably due to an allergic reaction to the saliva of the louse.

Pruritus is the first symptom, but it is variable in intensity according to the individual susceptibility and previous contacts. Erythematous, two or three millimeters in size macules and papules can be present (Fig. 8). In long-lasting cases may be present other signs such as excoriations, eczematous lesions (Fig. 9), secondary pyoderma (Fig. 10), adenopathy (Fig. 11), slight temperature, irritability and fatigue due to loss of sleep for increased pruritus during the night, and rarely anemia.

Some Authors (46) established the amount of blood sucked in every meal by adult lice, males and females, and neanides. They established that in an infestation of medium intensity with 30 lice and comprehensively 90 meals a day, the amount of blood lost by a single infested child is about 0.008 ml a day. In case of exceptional infestation with more than 2.000 lice present on the scalp one child can lose almost one ml a day. These data really indicate that only exceptionally, in particular subjects with very numerous lice and predisposing factors, an infestation with head lice can be responsible for or deteriorate an anemic disease.

Pruritus and the above mentioned objective signs can rise the suspicion of pediculosis capitis. The latter is stronger during epidemics of infestation. However, the suspicion is not sufficient to prescribe a specific treatment. The objective pathognomonic signs of pediculosis


Fig. 8


Fig. 9

Fig. 8, 9, 10, 11: Pediculosis capitis should be suspected in case of lesions on the nape of the neck. The earliest lesions are erythematous papules (Fig. 8). You can also see on the same site an eczematous dermatitis (Fig. 9), pyoderma secondary to scratching (Fig. 10) and also inflammatory adenopathy (Fig. 11).


Fig. 10


Fig. 11

Fig. 12: Self-moving louse on the hair of an infested child.

Fig. 13: Neanide feeding on the glabrous skin (see also the same image magnified by a lens).

capitis are the evidence of self-moving lice on the hair (Fig. 12, 13) or more frequently after combing the hair with a fine-tooth comb. Unfortunately, this objective, pathognomonic sign is not always visible.

To diagnose pediculosis one should stay behind the subject with suspected infestation and carefully look at him/her hair, first of all in the retroauricular and occipital region, which represents the primary and preferential site of infestation. When self-moving lice are not visible, one should comb with a fine-tooth comb the entire hair, searching every time for some lice caught between the teeth of the comb. In subjects with long hair fine-tooth combing should be preceded by moistening the hair and then brushing it to remove knots.

More often one can see small, pyriform grains stuck on the hairs, 0.8 x 0.3 millimeters in size, of variable color and located at various distance from the follicular opening, namely the point from which the hair emerges from the scalp. We are facing the nits or eggs laid by the adult female. These nits are stuck on one side of one hair like a flag on its staff (Fig. 21), although the cement winds as a sleeve the hair. It is not possible to move the nit from the hair with a stroke of the index, unlike the common dandruff (Fig. 16). Holding the hair with the suspect nit between index and thumb (Fig. 15) and moving

Fig. 14

Fig. 15

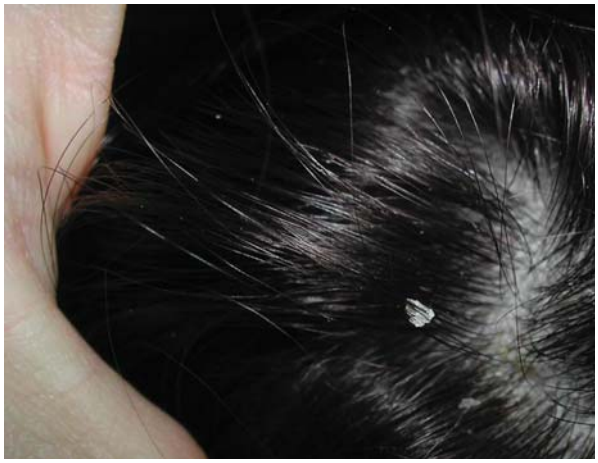

Fig. 16

Fig. 17

Fig. 14, 15, 16, 17: Nits of the hair in an infested girl (Fig. 14). Unlike the dandruff (Fig. 16), the nit is fixed to the hair, from which it can be hardly unthreaded (Fig. 15). The hair casts have different length from each other (Fig. 16).

the fingers from the scalp towards the distal extremity of the hair, when the finger reaches the grain, a clear obstacle is found. The nit can hardly run along the longitudinal axis of the hair and be unthreaded from its distal extremity. The strength necessary to unthread the nit from the hair, making it to slide towards the distal extremity of the hair, is inversely related to the distance of the nit from the scalp and directly to the length of the cement sleeve.

The nit is brownish in color when the embryo is vital, whereas it gets whitish (Fig. 18) when the neanide has gone out. The nits which are far less than six to ten millimeters from the scalp (Fig. 19, 20, 21) are brownish and vital, whereas the nits far more than one centimeter from the scalp are whitish and empty. This fact can be easily memorized, when taking into account that the egg is laid by the pregnant female level with the scalp and that it progressively move from the scalp while the hair grows. As the hair grows 0.3-0.4 millimeters a day and the egg takes about 10 days to hatch, one can understand why a nit far more than 1 cm from the scalp is almost always empty.

The differential diagnosis between vital and empty nit is very important because it is useful to assess the vitality of a colony, to decide whether a specific treatment is necessary or not and to monitor its effectiveness. It is not really right to treat a child with whitish, empty nits, far more than one centimeter from the scalp or to go on with treatment, although prejudice fears push in this direction. A clear example of these fears is the No Nit Policy, namely the policy according to which the children with nits on their hair, independently from assessing their vitality, should not be admitted in group activities. This

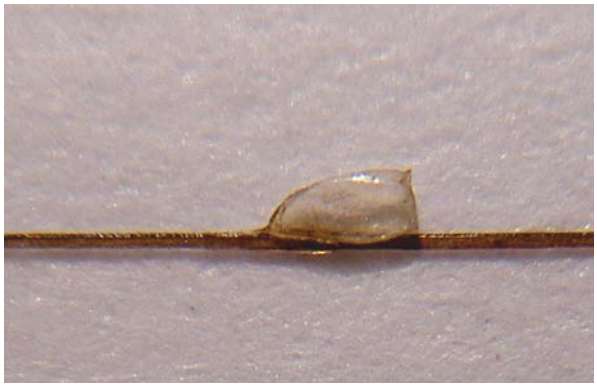

Fig. 18

Fig. 19

Fig. 20

Fig. 21

Fig. 18, 19, 20, 21: Empty nit, without operculum, transparent (Fig. 18). In Fig. 19, 20, 21 various stages of organogenesis, early (Fig. 19), intermediate with barely visible eye macula (Fig. 20) and mature with visible eye and legs (Fig. 21).


Fig. 22


Fig. 23


Fig. 24


Fig. 25


Fig. 26

Fig. 22, 23, 24, 25, 26: Empty, whitish, transparent nits without operculum, fixed to the hair and far more than one centimeter from the scalp (Fig. 22, 23, 24, 25). In Fig. 24 one can see a depression of the nit wall. In Fig. 26 nit without operculum, containing embryo disintegrated residua.

policy recently adopted by the Health Authorities of USA, Canada and Australia and strongly criticized by the experts (29), caused useless treatments and loss of school days to million children, with heavy psychological repercussions.

6.0 Differential diagnosis

In the areas where pediculosis capitis is endemic diagnosis and treatment are carried out at home because pediculosis is considered a nuisance and not a disease (45) and mainly because of the prejudice fear that an official diagnosis of pediculosis could bring discredit on the family itself. Under these conditions pediculosis capitis is more easily overdiagnosed.

On the other hand, school physicians, pediatricians and sometimes dermatologists should occasionally differentiate nits from dandruff and more rarely from hair casts. The dandruff (Fig. 16) is easily removed from the hair even with a shake transversal to the longitudinal axis of the hair, given with his/her fingers by the physician. The nit resists this shake and can only be hardly unthreaded along the longitudinal axis of the hair. The resistance of the nit is directly related to its closeness to the scalp.

Also cosmetic residua are differentiated from nits in the same way. On the other hand, the differentiation of nits from pseudo-nits or hair casts is more difficult (Fig. 17). Hair casts, for instance those ones associated with traction alopecia, are keratinous whitish masses, that wind the hair as a horny cylinder and can slide like the nits along the longitudinal axis of the hair. The hair casts are thinner -0.1-0.3mm- and mainly of variable -from 0.5 to 4 mm- length. Moreover, unlike nits, are not pyriform nor translucent and completely wind the hair (see dermoscopic diagnosis).

7.0 Dermoscopic diagnosis

The diagnosis of pediculosis has been recently enriched by the dermoscopic vision. The latter allows to better identify the morphological characteristics of the nits, adding new criteria to distinguish viable from no more viable nits, not only based on their distance from the scalp. Moreover, dermoscopy allows to see other unequivocal signs of the presence and viability of a colony of head lice.

To establish in pediculosis capitis the precise time of clinical and biological recovery is still a problem (13, 40). Until now the diagnosis of active pediculosis capitis, in absence of self-moving elements, was essentially based, as above mentioned, on the distance of the nits from the scalp.

Fig. 27

Fig. 28

Fig. 27, 28: Proximal brownish nit (Fig. 27), on dermoscopy (Fig. 28) viable, with operculum, in early organogenesis.

Fig. 29

Fig. 30

Fig. 29, 30: Viable nits with operculum, the one in Fig. 30 mature with eye macula.

Recently, morphological criteria (13, 40) of nit viability based on the use of dermoscope appeared in the relevant literature. The dermoscope, which has been already used in the study of scabies and other ectoparasitoses (1, 3, 13, 14, 40) could be useful in clarifying the problem of nit viability, thus enlarging that new research field shared by dermatologists and entomologists, which can be called entodermoscopy. These studies were aimed at establishing some morphological parameters useful in recognizing the viability of the nits, apart from their distance from the scalp, in order to evaluate their potential risk of contagiousness and/or to monitor the efficacy of treatment.

From a morphological point of view, in the nit one can distinguish a small and roundish bottom oriented towards the skin, a larger central body and finally a free border oriented towards outside (distal pole). With regard to the hair, to which it is cemented, the nit, especially the viable nit, describes an acute angle, with the proximal pole and central body attached to the hair, whereas the distal pole is free and separated by fractions of millimeter from the hair (Fig. 21).

During the dermoscopic observation of the nits we noticed a first significant difference based on the presence or not of the operculum on their distal pole. The nits without operculum -open nits- are usually empty (Fig. 18) and more than one centimeter far from the scalp. On dermoscopy examination, the latter are whitish, translucent with their distal border sometimes fissured. Some of these open nits, although lacking the operculum, are anyway occupied by some material reminiscent of the embryo or of parts of it (Fig. 26).

The nits with operculum -close nits- have variable morphology. On dermoscopic examination, some of close nits are light brownish and translucent. They have amorphous content (Fig. 28, 29) and uniformly tense and convex walls. Finally, they are the closest to the scalp and should be considered precocious viable close nits.

Other nits with operculum are dark brown. Inside their convex and tense walls an embryo occupies all the available space without significant void space. In case of advanced organogenesis the legs and an eye macule can be seen (Fig. 30). These mature viable nits are a bit more far from the scalp as compared with precocious viable close nits.

Finally, on dermoscopic examination other nits with operculum have not uniformly convex and tense walls. On the other hand, they show a roundish or longitudinal depression and should be considered as abortive close nits. The latter are not uniform in color, being partly brown and partly white, and show some air around the embryo, which is contracted or fragmented in more points (Fig. 32, 33, 34). These abortive

close nits are not uniformly far from the scalp. They can be very close to the scalp or far from it more than five millimeters.

With regard to the morphology of the nits, the open ones, namely without operculum, the shape of which is reminiscent of a cup, represent the involucre remaining after the discharge of the neanide. Their shape was reported even from a dermoscopy point of view (13, 40).

In the clinical practice these nits correspond to the white granules, leading to the diagnosis, unfortunately late, in most cases. Occasionally, open nits with residua of the embryo body can be seen (Fig. 26). The latter, which are usually closer to the scalp as compared with the empty ones, could follow the use of pediculicide products and/or of the mechanic activity of egg removing combs.

The relevant literature lacks a deep study of the closed nits, particularly of those ones we called abortive close nits, hypothesizing the death of the embryo contained in them.

In our temperate zone a fertile nit, in absence of favoring factors such as scarves or turtleneck pullover, is not far more than one centimeter from the skin of the salp (Fig. 27) and thus is hardly seen as compared with empty nits. The dermoscope, when properly used, can be useful in detecting early an infesting colony of lice, putting the viable nits in evidence when yet few and close to the scalp. The precocious viable close nit corresponds to their first stage of deve-

Fig. 31

Fig. 32

Fig. 33

Fig. 34

Fig. 31, 32, 33, 34: Nits with (Fig. 31, 32, 33) and without (Fig. 34) operculum with depression of the wall and fragmentation of the embryo body, as expression of abortion.

lopment before an evident organogenesis (Fig. 28, 29), whereas the mature viable close nits (Fig. 30) represent more advanced stages of development of the embryo.

The maturation of the latter takes about ten days, but it can stop inside the nit due to natural or therapeutic factors. Among the natural factors we should remember temperature and humidity. The lice are susceptible to the variation of temperature and to the reduction of the degree of humidity. The lice never leave their host and are susceptible to the variation of his/her temperature in case of fever, cooling or death. A slight -one or two degrees centigrade- increase of the skin temperature exalts their activity. However, when the temperature further increases, lice get restless and tend to find another host. Experimentally, a temperature higher than forty degrees centigrade kills the embryo. Moreover, the adult lice hardly move on a rough surface, do not like light and are attracted by dark objects (4).

When the humidity is less than 70%, the neanide is less capable to completely emerge from the nit after having opened the operculum, a phenomenon best described as stillbirth (26). The same phenomenon can be observed even after treatment with pediculicidal drugs (26). The latter likely damage the embryo entering the nit through the doughnut-shaped holes of the operculum, which under normal conditions allow air and water vapor to enter the nit. A fully developed embryo is more susceptible than an embryo in an early stage, namely present in a recently laid nit, to the neurotoxic activity of pediculicides (14, 28).

We showed (42) that the embryo damage can manifest itself even with other morphological alterations of the nit, such as contraction and fragmentation of the embryo body, presence of air cavities inside the nit and mainly of roundish or longitudinal depressions -abortive dimples- on the nit walls. When nits with abortive dimple develop during treatment, they could be expres-

Fig. 35: Two nits with abortive dimples on the hair.

Fig. 36

Fig. 37

Fig. 38

Fig. 39

Fig. 36, 37, 38, 39: Nits with operculum, but with depression of their wall and alterations of the embryo body, expression of abortion, can be observed *in vivo* thanks to the dermoscope.

sion of the damaging activity on the eggs of pediculicides.

However, before attributing this meaning to dimples of the nit walls, it is necessary to clarify whether the abortion of the embryo material can occur spontaneously. If the latter occurs spontaneously, it is also necessary to clarify what is its natural rate and which are the predisposing environmental conditions. A better knowledge of these complex mechanisms would play a significant role not only in the treatment, but also in controlling the spreading of the disease in a community.

As above mentioned, stillbirth (26), namely the death of the neanide before it is able to completely emerge from the nit, is related to unfavorable environmental condition. Stillbirth can occur due to unfavorable environmental conditions as a reduction of the degree of environment humidity, but also after treatment with pediculicides (26).

The latter likely damage the louse embryo entering the nit through the doughnut-shaped holes of the operculum, which under normal conditions allow air and water vapor to enter the nit. The neurotoxic activity of several pediculicides (14, 28) is related to the maturity of the embryo, being more significant in a mature, fully developed embryo than in an early stage embryo.

In a previous report (44) with the help of the dermoscope, a device that proved to be very

Fig. 40: Stillbirth: the neanide dies before emerging completely from the egg.

Fig. 41: Stillbirth *in vivo*.

useful for the study of other ectoparasitoses (1, 3, 13, 14, 40), we investigated the presence of feces of Pediculus capitis humanus as another possible sign of viability of a louse colony on the head. During the observation by the naked eye of a head infested by lice, besides rare self-

Fig. 42

Fig. 43

Fig. 42, 43, 44: Feces of head lice as black points on the skin of the scalp (Fig. 42) and close areas (Fig. 43, 44).

Fig. 44

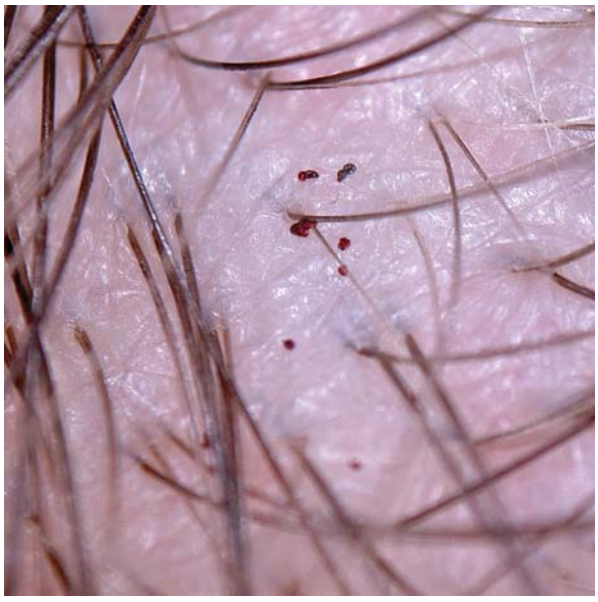

Fig. 45

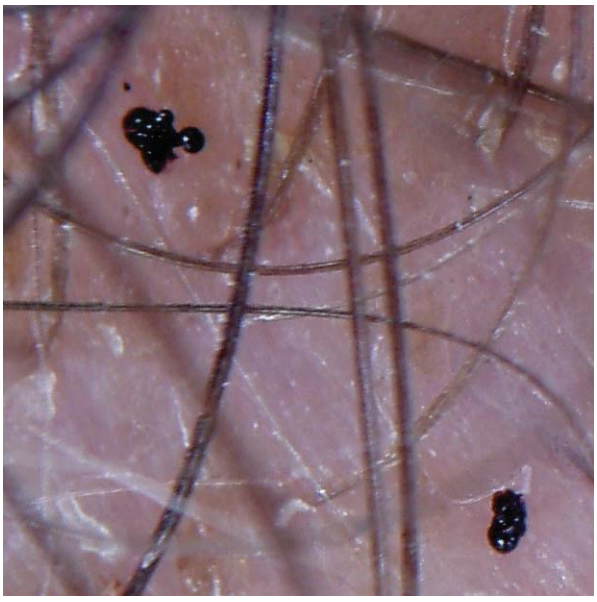

Fig. 46

Fig. 47

Fig. 48

Fig. 45, 46, 47, 48: On dermoscopic examination, the black points, sometimes stuck to the hair (Fig. 48), appear as humid spheres, reflecting the light, often clustered.

moving lice and nits of different morphology, more or less numerous and far from the scalp, it is possible to see barely visible blackish dots (Fig. 42, 43, 44). By the dermoscope at 10x magnification the blackish dots, which were barely visible to the naked eye, acquire a different shape, roundish or linear (Fig. 45, 46, 47, 48).

Thanks to the further magnification allowed by the optical zoom of the Digit-camera used to photograph the clinical findings (42), it is possible to put in evidence further characteristics of the louse feces. The latter characteristically consisted of clustered black globules (Fig. 48). These clustered globules were found stuck to the hair (Fig. 48) or laying on the scalp surface (Fig.

Fig. 49

Fig. 50

Fig. 49, 50: The neanide in Fig. 49 during its first blood meal, that changes the color of its body, dying it red and the neanide in Fig. 50 with 3 segment antennae, present red-brownish feces at their caudal pole.

Fig. 51

Fig. 52

Fig. 51, 52: Neanide seen in profile (Fig. 51) and from its abdominal surface (Fig. 52). You can see on the caudal pole the black, clustered feces, superimposable to those seen in Fig. 48.

45, 46, 47). In the latter case the globules seemed to lay on a liquid veil.

Besides the clustered blackish globules, also laminar black structures, in which globules progressively lost their spherical shape and their clustering tendency, were sometimes observed on the scalp.

Finally, it was possible to detect clustered black globules level with the caudal extremity of the louse (Fig. 49, 50, 51, 52).

The feces seen on the scalp can be easily differentiated from dust particles or drifts of other nature thanks to the characteristic clustered black globules, stuck to the hair or laying on the scalp. With time the clustered globules, probably because of their progressive drying, turn into black laminar structures with rather irregular borders. The black globules are really feces of the louse, as incontestably shown by the demonstration *in vivo* of the same structures stuck to the caudal extremity of the louse (Fig. 49, 50, 51, 52).

The black color of the globules is probably due to the coagulated blood of the host, that represents the only component of the louse feces. Given the strictly monothematic meal of the louse, this hypothesis could be easily confirmed by chemical reactions or identifying the blood group of the host.

As other ectoparasites of the skin of the genus dermatophagoides, the feces of the louse can be responsible for irritant and allergic phenomena and thus for pruritus and other complications due to the infestation with Pediculus capitis humanus. Their irritant capacity could be due to proteases present in the feces, whereas their sensitizing capacity could be associated with the enzymatic changes induced on the host blood by symbiont bacteria living in the intestine of the louse and allowing the utilization of the blood meal. This hypothesis should be tested in future studies.

Anyway, finding blackish clustered globules, stuck to the hair or laying on the scalp surface and close areas represents a new sign of the existence of viable elements of Pediculus capitis humanus and thus means that the infestation is active, can be responsible for contagion and needs a treatment.

On the other hand, the lack of dark globules stuck to the hair or laying on the scalp could be a further sign, together with the lack of self-moving lice and viable nits and with the presence of empty or abortive nits (6), of the therapeu-

Fig. 53

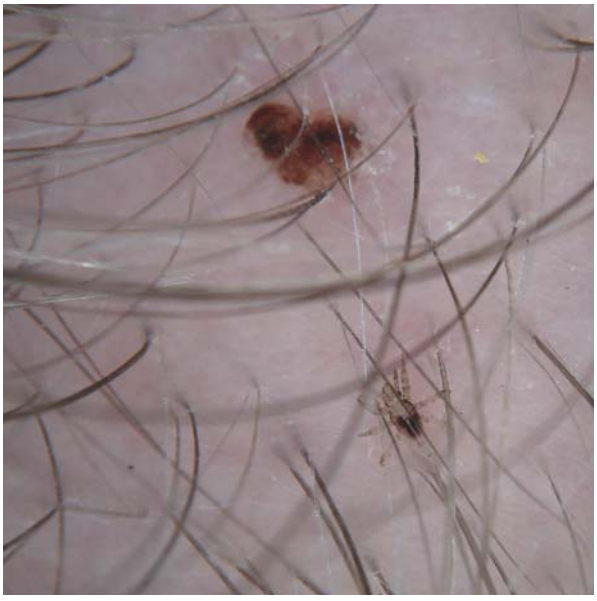

Fig. 54

Fig. 53, 54: Perifollicular erosion and hematic crust of the scalp (Fig. 53). These lesions are secondary to irritation caused by the louse as well evident in Fig. 54.

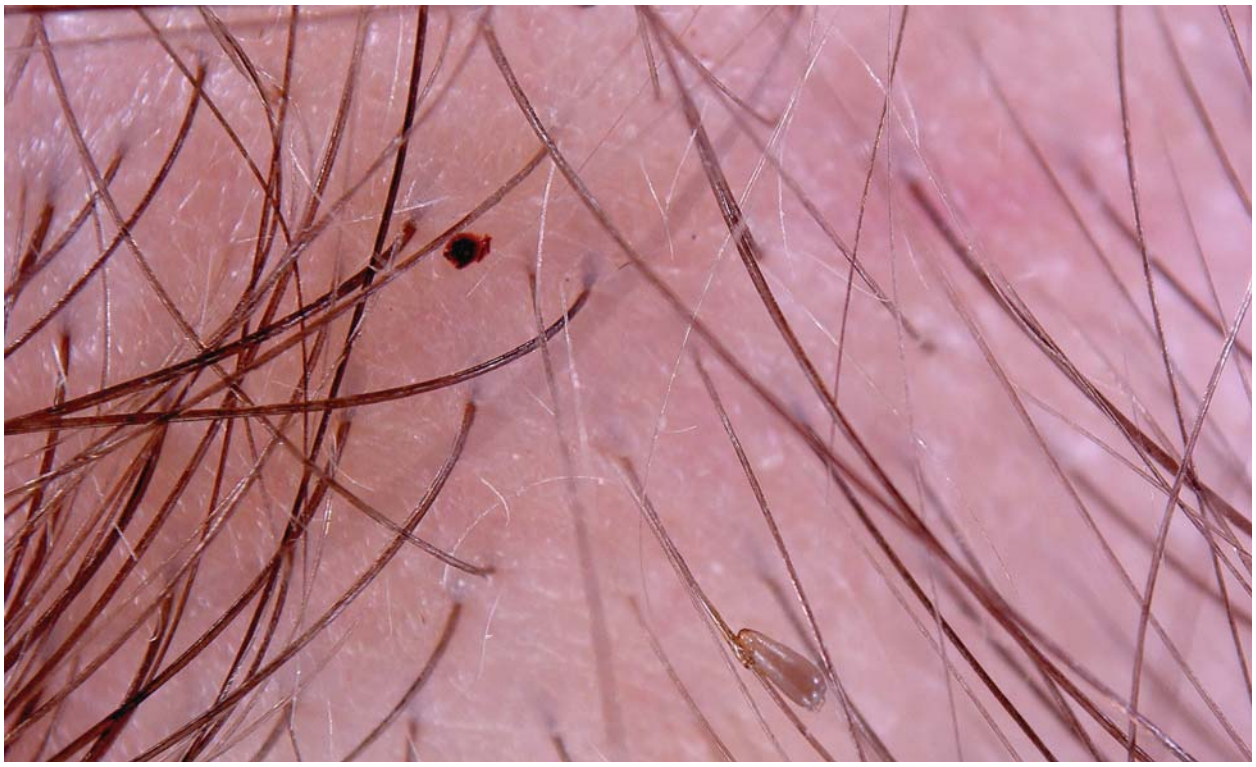

Fig. 55: Perifollicular crusted, hematic lesions associated to the presence of a viable, proximal nit.

Fig. 56: On the hair integument or exuvia left by a neanide after a molt.

tical efficacy of a pediculicide, the lack of contagiousness and thus of the unusefulness of a further treatment.

Moreover, thanks to the dermoscope, one can see another sign of the presence of a colony of viable head lice, namely the presence of integuments (Fig. 56) left by the neanides after their molt.

When the egg hatches, goes out a neanide morphologically identical to the adul louse, but smaller and without sexual differentiation. The neanide turns into imago or adult louse through three molts. During each molt the neanide gets rid of its stiff integument, that would really prevent its further growing. The empty integuments left by the neanide are well visible with the dermoscope.

Finally, the latter is very useful for the differential diagnosis, sometimes very difficult, between pseudonits or hair casts (Fig. 57) and nits (Fig. 60). The hair casts are very different in length from each other and mainly are cylindrical, not pyriform like the nits, as well visible also *in vivo* (Fig. 58).

Fig. 57

Fig. 58

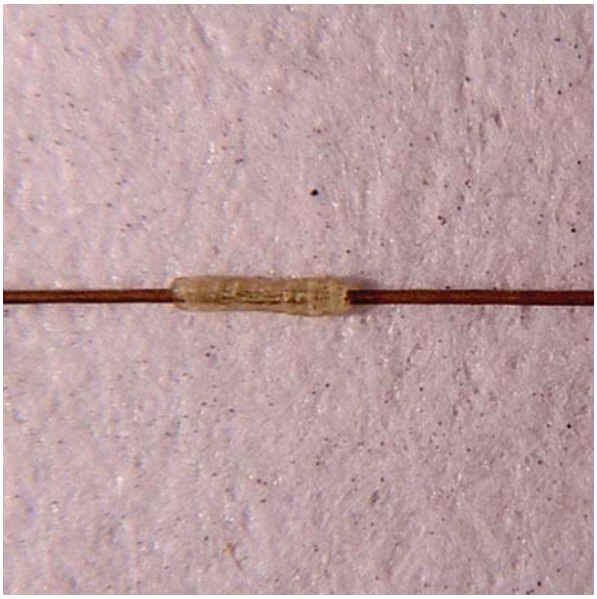

Fig. 59

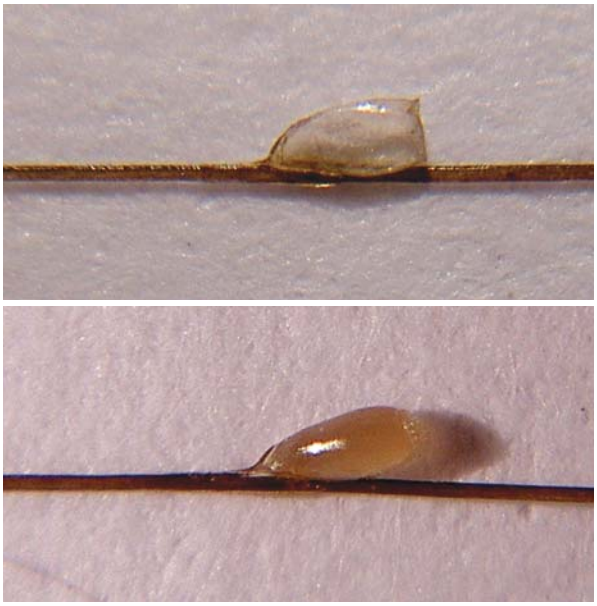

Fig. 60

Fig. 57, 58, 59, 60: Differential diagnosis of nits from hair casts (Fig. 57) by dermoscope. The hair casts are cylindrical (Fig. 58, 59) and not pyriform like the nits (Fig. 60).

8.0 Infectious complications

Pyoderma (Fig. 10) is the most frequent infectious complication of pediculosis capitis. Staphylococcus aureus is sometimes present on the healthy skin and almost always on the inflamed or eroded skin. Pyoderma is unlikely due to the sting of the louse, but probably secondary to the reiterated scratching with consequent erosion of the skin.

With regard to other biotic agents, Rickettsia prowazekii, which is responsible for epidemic typhus, and Bartonella quintana, which is responsible for trench fever, are classically carried out by pediculus corporis. Both these biotic agents were really present in body lice found in graves of soldiers of Napoleon's Grand Army, buried in Vilnius (Lithuania) during the retreat from Russia (35) or more recently in refugees of Burundi (34).

After the pioneer report of Charles Nicolle from Pasteur Institute in 1909 (18), most physicians and scientists were convinced that Pediculus corporis was the only vector of Rickettsia prowazekii. This is true from a clinical and epidemiological point of view. However, both the biotic agents were really found also in Pediculus capitis. Therefore, the possibility that the two infectious diseases can be also transmitted by Pediculus capitis cannot be completely ruled out (37, 39).

9.0 Prevention of pediculosis

Unlike some infectious diseases eradicated by vaccination, this is not possible for pediculosis. The persistence of pediculosis is probably related to the capability of head lice to develop resistance against a pediculicide drug, before a new one is introduced on the market.

Therefore, still today the prevention exclusively coincides with an early diagnosis in the subjects at risk of contagion and in the early treatment of the infested subjects, when a new case of pediculosis is diagnosed in a family or social group.

The treatment, which is not always devoid of side effects (40), especially with the first generation pediculicides, must always follow the proven diagnosis of pediculosis capitis.

After the treatment of the infested subjects, it is useful consider the objects that from a theoretical point of view could be contaminated. Taking into account that a temperature higher than 55°C for five minutes is lethal for lice and nits, the clothes theoretically subject to contamination are put in a washing machine. Brushes and combs can be washed with a pediculicide and immersed for 5 minutes in water at 55°C. The objects that do not tolerate this treatment, can be closed in a plastic bag for 10-15 days. An environment disinfestation of furniture, chairs and sofas is not necessary, due to the short survival of head lice far from the contact with the human skin.

10.0 Treatment of pediculosis

First of all we would like to underline that pediculicides, even those ones of new generation devoid of neurotoxic activity, should only be used in cases with proven infestation. On the other hand, pediculicides should never be used for the prophylaxis of healthy subjects at risk of infestation, because their effect does not persist for a long time and because they expose the patients and their family to distressing procedures from a physical and psychological point of view.

Physicians should also take into account that the actual pediculicides are not effective on all the nits. The very young embryos, wich lack the nervous system, are not damaged by neurotoxic pediculicides. This is why a second treatment is necessary after seven to ten days to be sure that all the viable eggs are treated in the period of maximum susceptibility to the drugs. Also the neanides recently emerged from the eggs could be this way killed.

10.1 Insecticides of first generation

Natural pyrethrins are extracts of Chrysanthemum cinerariaefolium, whose effectiveness against lice is well known from millennia.

Pyrethrin, jasmolin and cinerin are their active substances. Their activity is related to their blocking effect, although of short duration, on the sodium channels of the nervous system of the insect. Due to their short effect, since 1950 pyrethrins are always associated to piperonyl butoxide. The latter prolongs the nervous block till causing the death of the louse. Moreover, it is also able to prevent the development of resistance. Pyrethrins are not very resistant to heat and light, are not totally ovicidal and, finally, although rarely, may be responsible for allergic dermatitis due to repeated usage and for respiratory disorders in atopic subjects with pollinosis.

Permethryn is a synthetic pyrethroid derived from natural pyrethrins, resistant to heat and light and three times less toxic for mammalians as compared with natural pyrethrins. It is on sale with the name of Nix® or in generic drugs as 1% cream. Being provided with a persistent activity, initially in the '80ies only one application for ten minutes was effective. Today the well documented resistance of lice to the drug (29) makes a second application after seven days necessary.

Malathion is an organophosphate which irreversibly inhibits cholinesterase. It is the quickest acting product on the louse. However, it is potentially toxic, as well documented in agriculture with the pesticides. Malathion is available as alcoholic solution, gel and shampoo. The initially advised time of application for the alcoholic solution was about twelve hours during night. However, the smell of the product was responsible for headache under these conditions. Today the gel is used for ten minutes twice with an interval of one week.

Carbaryl is another inhibitor of cholinesterase with low toxicity for mammalians. It is used in lotion for long periods of time -even 24 hours- or as a shampoo with the same modalities of malathion.

Lindane is an organochlorine very commonly used in the past as shampoo for four minutes or alcoholic lotion during night time. A second application is necessary after seven days. Today lindane is infrequently used due to various reasons. It is not biodegradable, thus accumulating in the human body and in the environment. Moreover, it is potentially neurotoxic due to incorrect usage or ingestion and, finally, induces resistance.

Recently it has been shown that the ingestion of cotrimoxazole (sulfamethoxazole-trimethoprim), has pediculicide activity, probably because the antibiotic kills the symbiont bacteria, contained in the mycetoma, that are essential for the life and reproductive capability of the louse. Unless the infested child is also affected by pyoderma, this antibiotic association is not indicated for the treatment of pediculosis.

10.2 Natural pediculicides

In the '90ies the introduction on the market of a new natural pediculicide raised a great interest. It consisted of extract of coconut, two natural oils -anise oil and ylang ylang oil- and isopropylic acid (27, 28). This product, introduced in Israel, then in the United States with the name of HairClean 1-2-3® and in Europe with the name of Paranix® (Chefaro, Ireland), acts in a manner different from all the other products, occluding the tracheal lumen of lice and thus inducing their death by suffocation.

The product, devoid of toxicity and unable to cause resistance, has a good pediculicide activity. It should be sprayed on all the hair and kept for fifteen minutes. The treatment should be repeated after nine or ten days. The natural oil-based product showed (41) an efficacy equal to malathion used in the control group. In most cases, monitoring the process of recovery by daily combing with the enclosed fine-tooth comb, the recovery was obtained within three days from the first application of the product. A subsequent report (43), although carried out in a limited number of cases, confirmed the efficacy of the drug after a single treatment followed by systematic daily combing with fine-tooth comb.

The interest for this therapeutical approach was so great that, starting from the appearance of the natural-oil based product, no new pesticide products were introduced on the market, in contrast with the appearance of very numerous products based on natural oils or anyway provided with physical activity on the louse.

The pediculicide activity of Eugenia caryophyllata bud and leaf oil-derived was comparable to that of pyrethrum (51). The Authors also studied the pediculicide activity of its components, showing that the strongest activity is attributable to eugenol followed by methyl salicylate. Some Authors (52) studied the oil-derived products of Eucalyptus globulus, showing that its pediculicide activity is greater than pyrethrum and identifying in 1,8 cineole monoterpenoid the strongest activity. In another report (53) the pediculicide activity of essential oil-derived from 54 plants was studied, showing that extracts of eucalyptus, maryoram, penny-royal and rosemary are more effective than pyrethrum.

On the other hand, the essential oils derived from Cinnamomum zeylanicum showed a minor activity than pyrethrum. Priestley et Al. (33) studied the activity of essential oils both on the louse and nits, showing that terpinen-4-ol is the most active of the mono-oxygenated monocyclic compounds against the adult louse, whereas nerolidol, although being not active on the adult louse, is particularly lethal for the nits.

Other Authors (21) studied the pediculicide activity of crude extracts of Annona squamosa seeds and of its more important components, as the oleic acid and triglyceride with one oleate ester, showing that the latter is the most effective. The oil extracts of Melia azedarach showed high pediculicide activity and proved able to inhibit going out of the neanide from the nit. Toloza et Al. (49) studied both the pediculicide and repellent activity of oil extracts of various types of Eucalyptus and some of their hybrids, for instance E. grandis and E. caldulensis. They showed that the hybrids contain less number of ingredients than pure species, allowing a better chemical identification and manipulation of the individual compounds.

The essential oil of Hedychium spicatum showed *in vitro* stronger pediculicide activity than a product containing 1% permethrin (22). The essential oils of lavender, peppermint and eucalyptus showed significant pediculicide activity (22). The latter was increased by adding 1-dodecanol. The essential oils of tea and lavender were more effective than lemon oil on the head lice, whereas all three oils were effective against mites (59). The monoterpenoids contained in some essential oils, particularly 1,8-cineole, are able to inhibit acetylcholinesterase. However, the toxicity of these essential oils on the viability of the head louse occurs before the inhibition of acetylcholinesterase (31).

A product containing 4% dimeticone lotion proved more effective than 0.5% malathion against the head louse (87).

The mechanism of pediculicide activity of dimeticone is not well known. Dimeticone could form a film impermeable to the air around the louse or penetrate and block its respiratory openings. Some Authors (30) showed with *in vivo* experiments that a few hours after an apparent loss of viability, the louse treated with 4% dimeticone (Hedrin®) recovers and the mortality ratio is comparable to that of not treated lice. The apparent contradiction between these two reports can be explained by a lower concentration of dimeticone in the product, because a product with higher concentration of dimeticone (Nyda®) showed greater activity. It can be explained also with the shorter duration of exposure *in vitro*, given that dimeticone in the clinical use should be kept on the head for a much longer time -8 hours-.

In Italy, after the success of the first product based on extract of coconut and anise and ylang-ylang oil (this success was confirmed also in the Italian edition of the handbook of evidence based medicine) were marketed in the last year numerous pediculicide products based on oil of coconut, Neem, tea, andiroba, colza, dimeticone and simeticone. Three of these products contain a professional comb. They should be applied for a time variable from the fifteen minutes of Paranix® to the eight hours of Hedrin. The indication for a second and a third treatment are also variable.

The success of essential oils in the treatment of pediculosis capitis depends on various factors, first of all on the minor potential toxicity for children and minor persistence and polluting activity for the environment, being comparable the pediculicide activity. Moreover, these products, at least from a theoretical point of view, should not cause resistance in the head louse,

given the physical mechanism of their activity. The last factor contributing to their success is their nature of vegetable extracts, always appreciated by the general public and whose activity was property of the popular medicine from much time.

Most essential oils derive from distillation of spontaneously growing or cultivated plants (19). From a chemical point of view, the essential oils consist of a mixture of hydrocarbons -terpenes and sesquiterpenes- and oxygenated compounds -alcohols, esters, ethers, aldehydes, ketones, lactones, phenols and phenolic ethers-. There are three thousand types, three hundred of which provided with commercial value, of these essential oils. The latter are often responsible for the particular perfume of the plant from which they derive.

In the packaging of the first product based on coconut extract and two natural oils -anise and ylang ylang- there is a professional comb provided with very close -0.3 millimeters- metal teeth. This comb is useful for diagnostic purposes but also to monitor the efficacy of the treatment. In pediculosis capitis, independently of the type of product used, it is really very important to remove all the nits that persist on the hair after the pediculicide treatment. From a theoretical point of view, removing nits would be not necessary if there was a treatment able to kill all the adult lice, neanides and eggs. Unfortunately, this treatment does not exist. There is not above all an ovicide treatment.

When in the ’90ies permethrin appeared on the market, the percentage of definite recovery after a single treatment was 95-98% (48), due to its persistent activity on the scalp and its lethal effect on the emerging neanides, although its ovicide effectiveness was less than 70%. However, a decreased response to permethrin was reported in Israel, (29), Czechoslovakia (38), Great Britain (5), United States (32), Argentina (15) and Australia (20).

The decreased response to permethrin is due to mutant strains of lice who develop resistance to the drug. Particularly, the point mutation T929I of the alpha subunit of the sodium channels is the most important cause of resistance to permethrin of the head louse (55). This is why actually a second application of permethrin after 7 days and possibly a third one after another week is adviced. This is why in the United

Fig. 61

Fig. 62

Fig. 61, 62: The comb with metal teeth with rounded ends (Fig. 61) must be used starting from the scalp and tangentially to it for the diagnosis and to monitor the treatment (Fig. 62).

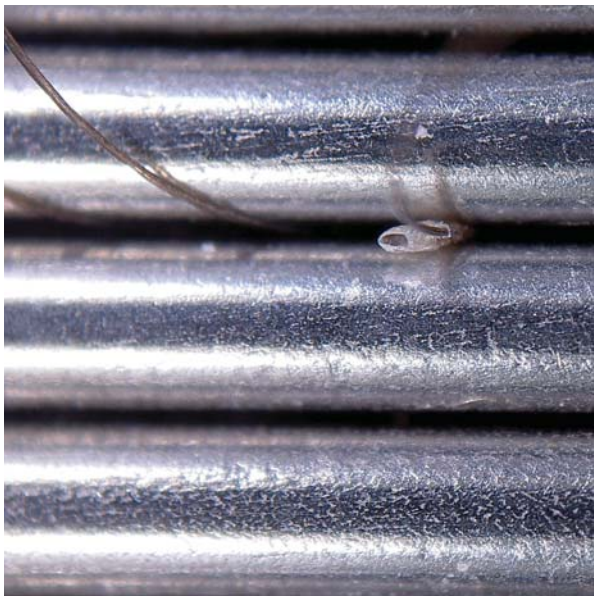

Fig. 63

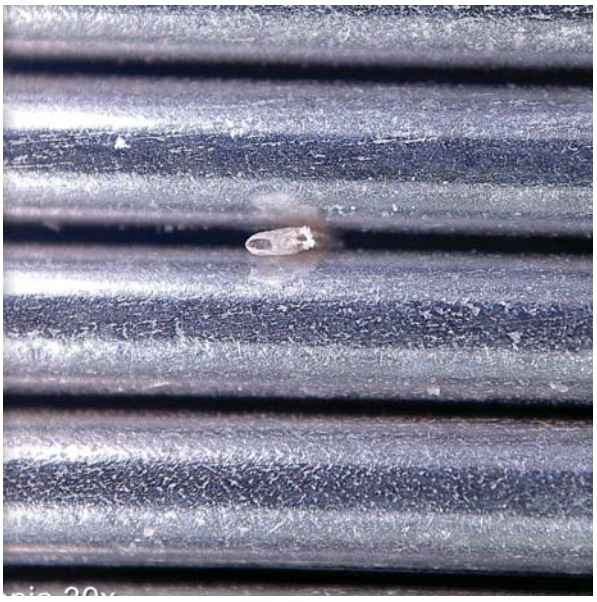

Fig. 64

Fig. 65

Fig. 66

Fig. 63, 64, 65, 66: The professional comb unthreads also a nit (Fig. 63, before unthreading it from the hair and, Fig. 64, after having unthreated it). Irritant scalp dermatitis (Fig. 65), seen by dermoscope (Fig. 66), due to excessive treatment.

States several years ago passed, although later on hard attacked, the No Nit Policy, namely the prohibition to return to school even in presence of a few not viable nits. Finally, this is why it is useful removing, as precociously as possible, the nits, after the first pediculicide treatment, whatever type of treatment was carried out.

The techniques to remove the nits can be classified as follows (46): 1- removal of infested hairs a) cutting the hair above the nit or b) cutting completely the hair; 2- removal of the nits from the hair unthreading them towards the distal part of the hair a) manually, b) with a professional comb, c) with a comb in association

with a lubricating substance favoring the slipping of the nit along the hair; 3- melting the cement that anchors very strongly the nit to its hair.

1a is possible, although requiring a lot of time, whereas 1b cannot be suggested because of esthetical and psychological problems, although very quick. With regard to the other options, the physicians should first of all remember that the nit is stuck to its hair by a sleeve of proteic cement, that goes out from the vagina before the egg. Lapeere et Al. (24) measure the energy necessary to move the nit along the hair, more precisely the initial energy necessary to move the nit, the maximum energy and the average energy during the proximal-distal movement. They showed that the energy is directly related to the length of the cylinder of cement and inversely related to the distance of the nit from the scalp. Therefore, unthreading the empty nits, far from the scalp, especially if the cylinder of cement is shorter, is easier.

The physicians should also take into account that actually a solvent capable of melting the cylinder of cement does not exist (10) and that the proposed remedies, such as diluted vinegar and 8% formic acid show in vitro scarce effect on the cylinder of cement (8).

After these elucidations, one can understand that option 3 is impracticable. With regard to point 2, the option a was until now that one more frequently practised and probably it is still the more likely now, whereas options b and c require the use of a professional egg unthreading comb.

Speare et Al. (46) compared the efficacy of two combs, one with metal rounded teeth and another more economic with plastic teeth. The difference between the two combs was in their ability to remove nits. The comb with metal teeth removes more nits. With regard to the use of lubricating substances, the latter probably make combing less traumatic and more easy.

As above mentioned the professional comb, which is able to unthread the nits, is useful for the diagnosis. Moreover, it is also useful to monitor the efficacy of the treatment with daily combing of all the hair, lock by lock, starting from the scalp.

Professional combs are provided with non-deformable teeth, that are distant from each other less than 0.5 millimeters, better when provided with a rounded end able to penetrate among the hair without hurting the skin. The metal combs, after having combed every lock, should be cleaned with a paper handkerchief. After the use they can be sterilized in boiling water and then used again.

10.3 A new therapeutical proposal for pediculosis capitis

This proposal takes into account the resistance against the chemical insecticides actually used and the necessity of removing physically the nits, because there is no 100% ovicide treatment. This necessity also derives from the comparative observation of the behavior of other mammalians. The wild mammalians protect themselves against the parasites catching the latter with their teeth and bathing repeatedly. Moreover, the mothers of wild mammalians are very efficient in removing the lice of their cubs before the latter learn to do it by themselves. When humans are involved, the physical removal of the nits is also necessary to avoid excessive amounts of chemical products, that especially in the past were not completely devoid of toxicity for the child and the environment.

The physical removal of the nits should be carried out as soon as possible, also due to psychological reasons. However, the return to school of the already treated child should be not conditioned by their preventive total removal, according to the above mentioned No Nit Policy, which was strongly criticized for the loss of day school and the psychological repercussion on the child.

Finally, the physical removal of the nits takes into account our experience with the use of natural oils and daily monitoring with professional comb (41, 43). In our opinion the success of the therapy essentially depends on the first pediculicide treatment and the care taken by the responsible relative in removing all the nits through an adequate combing by a professional comb with metal rounded teeth.

NEW PROPOSAL FOR THE TREATMENT OF HEAD LICE

1- Treatment immediately after the diagnosis with natural oils characterized by short time of application (15-20 minutes), sprying carefully the product on the entire scalp till to moisten it completely. The amount of product to be used should be related to the mass of hair to be treated. Combing immediately after the treatment, exploiting the lubricating effect of oils or of an after-shampoo favoring the removal of nits, lock by lock, till the complete removal of lice and nits;

2- Daily combing when coming back home from the school, in order to intercept possible new lice deriving from children who do not yet know to be infested, with a professional comb, for at least four days, anyway till neither lice nor nits are found for two consecutive days;

3- From that moment combing with professional comb every three days for four times;

4- When in one of these sessions of combing are found lice, one starts again from point 1. When nits are found, one starts again from point 2.

11.0 Fulfilments of the family, teachers and physicians

The family is the first moving force in the fight against pediculosis. However, in many cases, families should be properly educated by physicians about the modalities of contagion, the indication to the treatment and, finally, its modalities. Since 1992 in Italy the report of contagious disease is no more compulsory. The parents themselves certify that the first pediculicide treatment has been carried out or that it has not been made because their child is not infested. This way the child does not lose any school day.

The teachers inform the parents about the presence of confirmed cases of pediculosis within the school and thus about the opportunity that their child undergoes an examination to unveil a possible infestation. The teachers also give the parents the first information regarding the infestation, when requested. In particular cases of persistent infestation with head lice, the teachers can ask for a medical certificate of non contagiousness.

The school physician and the pediatrician give the family more detailed information about the infestation and visit the child and his relatives with possible infestation. When requested, physicians give the parents a certificate of non contagiousness.

Nothing else is necessary except for these fulfilments. Particularly, general disinfestation of the school or the environment in which the subject infested by head lice lives is not necessary.

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