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Asymptomatic dermatophyte scalp carriage: laboratory diagnosis, epidemiology and management

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Abstract Asymptomatic carrier is defined as an individual who has dermatophyte-positive scalp culture without signs or symptoms of tinea capitis. The prevalence of asymptomatic carriage differs from region to region with a rate of 0.1–49%. Anthropophilic dermatophytes, *Trichophyton tonsurans* and *Trichophyton violaceum*, have been generally associated with high rates of asymptomatic carriage. Hence, the presence of dermatophytes on healthy scalp hairs of children may be a potential source of infection for schoolmates, playmates and/or households. Although it was also reported in adults, most carriage has been observed in children especially among those between 4 and 8 years of age, while male to female ratios vary between studies. It is still unclear, whether carriers should be treated with topical antifungal shampoos or oral antifungals or both, as some studies indicate that some untreated cases become culture-negative after 2–12 months. This review provides details on related dermatophyte fungi, laboratory diagnosis, epidemiology, ways of spreading as well as treatment and follow-up results of asymptomatic carriage. An integration into the school health programs is proposed, which will render the possible dealing of the subject in a comprehensive and reasonable manner.

Keywords Asymptomatic carriage · Dermatophyte · Diagnosis · Epidemiology · Therapy

Abbrevations

AC	Asymptomatic carriage
STC	Symptomatic tinea capitis

Tinea capitis: definition

Tinea capitis is a dermatophyte infection of the scalp hairs and intervening skin [1, 2]. The condition is generally observed in children with a median age of 4 years [3], ranging between 6 months and before puberty [1]. Symptomatic tinea capitis (STC) has three main clinical forms: namely (i) tinea capitis superficialis (non-inflammatory form), (ii) tinea capitis profunda (inflammatory form, kerion Celsi), and (iii) tinea capitis favosa (favus) [1, 2]. The non-inflammatory form may have a variety of clinical presentations, including 'gray-patch' scaling, seborrheic-dermatitis like scale, hair thinning without significant scaling, and distinct patches of 'black-dot' alopecia [2, 4]. It is generally associated with

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anthropophilic dermatophytes, *Microsporum audouinii*, *Trichophyton tonsurans* and *T. violaceum*, and zoophilic *M. canis* vary from region to region [1, 2, 4, 5].

Inflammatory tinea capitis may also have multiple clinical forms, including localized pustules that are similar to impetigo and multiple widespread abscesses that mimic dissecting cellulitis [2, 4]. Kerion Celsi is most commonly associated with zoophilic *T. verrucosum* and *M. canis* or geophilic *M. gypseum* [1, 4–9]. The favus form, a process producing cub-shaped crusts called scutula, has been described with anthropophilic *T. schoenleinii*, but may also occur with *T. violaceum*, *T. verrucosum* or *M. gypseum* [1, 2, 5–8]. Moreover, both kerion Celsi and favus may have result in alopecia with scarring. Hence, the signs and symptoms will vary depending upon several factors like the causative organism and the host immune response [2].

Dermatophytes remain the single most common cause of human fungal infections worldwide [10]. Furthermore, tinea capitis is the most contagious of all the tineas caused by dermatophytes. The production of large numbers of arthroconidia, whether inside the hair shaft (endothrix) or outside it (ectothrix) contributes to the spread. Small-spore ectothrix infections (e.g., by *M. audouinii*) potentially spread rapidly and often cause epidemics in schools and orphanages [2, 11]. Whereas, endothrix infections like *T. tonsurans*, however, are more likely to result in small outbreaks among family members or intimate friends where the organisms are not endemic (e.g., Japan), while this is not the case where the organisms are endemic (e.g., North America, Africa) [11]. The favic infections resulting in along hyphae inside hair reduce contagiousness by direct contact among close family members [11].

Asymptomatic dermatophyte scalp carriage

Tinea capitis may also present as a minimal infection, termed 'carrier state'. Asymptomatic carrier is defined as an individual without signs or symptoms of tinea capitis, and as someone who has dermatophyte-positive scalp culture [1, 4, 5]. In a historical perspective, clinical and microscopic features of the causative agent of tinea capitis, in particular favus dates back to the 1840s [1, 2]. MacKenzie et al. [12] were among those first to recognize the carrier state in tinea capitis in the 1960s. The authors described many features of this state in their investigation of an outbreak of tinea capitis caused by *T. tonsurans* in a boarding school in Northern Ireland. They detected positive fungal cultures in hairbrushes and on clothing of several children who were not 'ostensibly infected' and noted 'exceptional difficulty in detecting infection' in some cases in which eight or nine examinations were needed before establishing a diagnosis of tinea capitis.

Although the presence of dermatophytes on seemingly healthy scalps were reported as a transient carrier state in cross-sectional studies [13, 14], longitudinal studies demonstrated that these carriers had played a role in the spread and the persistence of STC in the community [10, 15–17]. In literature, it was documented that the asymptomatic carriage (AC) of dermatophytes could be related to the contact with cases of STC [12, 15, 18]. Moreover, recurrence or re-infection with STC was not uncommon after adequate oral treatment [19]. This has led to a growing awareness that carriers constituted a major reservoir of infectious organisms that produced STC [1, 2, 4, 5]. In literature, however, there is no data showing that isolates cultured from scalp carriers are genetically identical (i.e., the subspecies) to those of patients with symptomatic infections living in the same environment. In a study, the idea whether active disease represented acquisition or activation of the pathogen was considerably argued, and it was found that symptomatic diesase seemed to represent the activation of a single strain that persisted on the scalp [10].

Related dermatophyte fungi

Anthropophilic dermatophytes, i.e., *T. tonsurans* [10, 12, 14, 16, 17, 19–24], *T. violaceum* [25–27], *M. audouinii* [15], *M. ferrugineum* [13], and *M. rivalieri* [28] have been generally associated with high rates of AC. This was attributed to a relative lack of host response, hence these fungi were thought to be good candidates for AC [29]. Abdel-Rahman et al. [10] noted that the undefined factors that permit *T. tonsurans* to avoid clearence and to remain on the human host in a subclinical state contributed to the ability of the organism to effectively persist and thrive in the

population. The authors also genotyped the clinical isolates, while no relation was found between sequence variations in the rRNA locus and the disease phenotype. In some other studies, *T. concentricum* [30], *T. gourvilii* [13, 28], and *T. soudanense* were detected [13, 15, 28]. Interestingly, two reported *Epidermophyton floccosum* isolation from carriers [13, 30]. Furthermore, it is well known that this species is a sporadic cause of STC [31, 32]. It was also reported that *T. schoenleinii* was recovered from a carrier case [26].

In contrast, zoophilic organisms usually present with a symptomatic inflammatory response, and they less likely lead to AC [1, 4, 13, 22, 33, 34]. However, more recently, *M. canis* [30, 35] and *T. mentagrophytes* [35, 36] were reported as predominant species (see Table 1). Geophilic species, *M. nanum* [30], *T. terrestre* [37], *T. ajelloi* [23], and *M. gypseum* [23, 36] were reported to be associated with AC, albeit in a decreased level.

Laboratory diagnosis: how?

Sampling procedures

Asymptomatic carriers have no evidence of hair shaft invasion confirmed by direct microscopy [1, 4, 33, 38]. Hence, direct microscopic examination of the hair root is unnecessary [4, 38]. Brushing the scalp with plastic scalp brushes builds up static electricity on the brushes, which attracts particulate material (including fungal propagules) adsorbed onto the prongs of the brushes. This material is dislodged when the brushes are inoculated onto the agar surface [15]. For example: toothbrushes will trap particulate material between the bristles, which are then dislodged when the plates are inoculated. The scalp massagers work well when dry, but moistening the cotton swabs is also conducive [39]. However, samples may be collected by different procedures, i.e., after cleaning with 70% alcohol [34, 36] or directly swabbing after dipping the hairbrushes in a sterile Teepol solution [15] or in 0.1% Tween 80 [30] or toothbrushes in the latter [17].

Table 1 The most common dermatophyte species related with the carrier state

Species	Reference no.
Anthropophilic	
M. audouinii	[15]
M. ferrugineum	[13]
M. rivalieri	[28]
T. tonsurans	[10, 12, 14, 16, 17, 19–24]
T. violaceum	[25–27]
Zoophilic	
M. canis	[30, 35]
T. mentagrophytes	[35, 36]

If the patient is a suspected carrier and with no observable lesions, different areas of the scalp like frontoparietal, temporoparietal, occipital, and biparieto-occipital areas should be sampled [38]. Today, the diagnosis of the carrier state is only possible by culturing using the hairbrush [12, 13, 15, 22, 23, 25, 28, 30, 36], toothbrush [10, 14, 17, 19, 21, 26, 36], cotton swab [35, 36], scalpel blade [16], carpet disc [34], or gauze [24] methods.

Akbaba et al. [36] observed that the hairbrush method was significantly found to be more effective in detecting dermatophyte fungi than the toothbrush ($P < 0.01$), and the cotton swab methods ($P < 0.05$). There was also a statistically significant difference between the use of a single method and the combination of all other three methods ($P < 0.005$). For laboratory diagnosis, no method was found to be nominated as a gold standard; hence a combined use of diagnosing methods was suggested by the authors. All in all, these methods are simple, inexpensive, require little expertise with minimal training time and very little time to actually perform the procedure as well as being not threatening or traumatic [16, 24, 34, 35, 39].

The hairbrush method also seems to better diagnose also index cases of STC making it possible to examine some of the scales obtained by microscope, whereas this would be very difficult to do with moistoned swabs [38]. Sugita et al. [40] described a real-time TaqMan PCR assay as a culture independent method for rapid detection of *T. tonsurans* from hairbrushes from patients with STC, enabling the detection within 5 h. This method was also successfully used for diagnosing both symptomatic and asymptomatic tinea corporis cases among combat sport club members [41].

On the other hand, Hubbard and de Triquet [42] detected that brush method is a reliable, painless, and

more expedient way to obtain cultures from children with STC. Friedlander et al. [39] compared the cotton swab method with the toothbrush method in diagnosing STC, and concordant results were recorded by using both methods. Although, Head et al. [43] used cotton swab method for evaluating dermatophyte infections, it is not routinely used. More recently, Bonifaz et al. [44] compared the cytobrush-culture method versus standard method (scraping the scalp to remove hair and cell debris) to diagnose STC in 135 culture-positive cases. The authors found 97% versus 85.1% isolation rates with an average of 8.5 days versus 11.2 days until positive, respectively ($P = 0.025$).

Fungal culture

The specimen must be inoculated onto Sabouraud glucose agar amended with a mixture of 100 μg cycloheximide ml^{-1}, 100 μg of chloramphenicol ml^{-1}, and 50 μg of gentamicin ml^{-1} to reduce the growth of bacteria and saprobic organisms. The culture plates and/or slants are incubated at 25°C in air for 1–4 weeks [1, 2]. Grown fungal colonies are identified according to either classical [2] or molecular-based methods [10].

Spore load: why is it important?

A quantitative approach to culture is in the experience of most laboratories and this can be done with any brush-based technique, i.e., hairbrush [13, 23, 28, 30, 36] or toothbrush [19] methods, but it is more difficult with other methods like cotton swab method [35, 36]. The advantage of spore load counts illustrate the degree of contagiousity of carriage, providing a foresee on how AC would be handled, whether clinical lesions would develop, whether AC would continue or whether it would become culture-negative [15, 17]. Before treatment initiation, a quantitative culture is recommended. Hence, a total colony count (equivalent to number of spores retrieved) must be obtained for each carrier [11].

A quantitative method was used with significant success to distinguish between carriers and infected individuals [28, 45]. Individuals whose culture plates exhibited fewer than 10 colonies were regarded as being carriers, and those with more than 10 as infected cases. In a study, 18% of carriers represented true infections, and treatment was found to be necessary [17]. However, the question whether treating carriers with low spore counts is necessary or not remains unanswered [11]. For example, in a study, 97% of carriers had a spore load of less than 10 colonies per carrier [30]. More recently, Akbaba et al. [36] demonstrated a high spore load in two (12.5%) of the 16 carriers with the use of the hairbrush method.

Asymptomatic carriers, who had low spore loads, and were likely to lose their carrier state, were transiently colonized with spores. Alternatively, carriers who had very high spore loads and were more likely to remain culture-positive overtime may have had heavy colonization or an occult infection producing numerous spores [13, 17, 30]. Carriers with very high spore loads may be more important vectors than index cases in the transmission of STC. Because these cases are undetected, the potential exists for large numbers of spores to be shed over long periods of time, i.e., 6 weeks–12 months [34, 46].

Wood's light examination

The utility of Wood's light examination is based on whether the organism is an ectothrix or endothrix. The best-known agents of ectothrix STC are *M. audouinii*, *M. canis*, *M. distortum*, *M. ferrugineum*, and *M. gypseum.* The latter produce dull yellow fluorescence, while the other species bright-green. However, *T. schoenleinii*, presenting with endothrix colonization of the hair shaft, fluoresces a faint blue color [47]. The use of Wood's light in AC is limited, because most of the dermatophytes associated with AC like *T. tonsurans* and *T. violaceum*, do not fluoresce. Ive [15] followed-up 19 asymptomatic carriers—mostly due to *M. audouinii*—and found that, three had STC and four were fluorescent at the fourth month. Recently, however, we detected two carriers with *M. canis*, which were negative in Wood's light examination [35].

Epidemiology

Geographical distribution

The ecology of dermatophytes is dynamic and highly variable from region to region around the world and,

therefore, epidemiology and risk factors depend on these parameters. It tends to be affected by periods of social change featuring changing immigration patterns, health habits, standards of living or propensities for travel [2]. The behavior of a population of organisms and, consequently the rates of symptomatic and asymptomatic disease, will vary based on whether the organism is endemic in the area or only responsible for sporadic infections in the area. There is no doubt that the ecology of the fungi, the epidemiology of infections with dermatophytes, and the socio-demographic characteristics have changed with time.

The predominant species of AC were reported as *T. tonsurans* in North America [10, 14, 16, 17, 20, 21, 24], *T. violaceum* in Africa [25–27], *M. canis* in Middle-East [30], while Europe witnesses a dispersed flora consisting of *M. ferrugineum* [13], *M. rivalieri* [28], *T. tonsurans* [19, 22, 23], and zoophilic *T. mentagrophytes* [36].

Prevalence

The prevalence of AC varies considerably, but generally correlates well with the incidence of STC in the local population [22–24, 26, 30, 35]. In Europe, for instance, where STC has been relatively uncommon, *M. canis* was reported as the most common causative agent as well as *T. tonsurans* being an emerging pathogen [48]. The prevalence of AC in school children in Europe was reported to be between 0.1 and 1.3% [22, 23, 35–37], except in the UK, where it was 4.9% [28]. The rate was observed to reach values as high as 14% in a parochial school [17] and 16% [14] in the household contacts of patients with STC in the USA, where *T. tonsurans* STC was endemic. There was only one report from Middle East (Palestine) with a prevalence rate of 0.8% with *M. canis* predominancy [30].

Asymptomatic carriage rates were reported as 4.5, 17, and 24.5% in Egypt [27], in Ethiopia [26], and in Nigeria [15], respectively, with *T. violaceum* heading the list. In contrast, higher prevalence rates (49%) of AC were reported in the Cape Peninsula of South Africa, where *T. violaceum* tinea capitis was endemic [25]. On the other hand, there may be different rates of detection of AC and STC in a population, but most studies indicate that the dermatophytes belong to the same species, particularly where anthropophilic species are involved [25, 26]. In addition, Ghannoum et al. [24] state that variation in these prevalences may reflect differences in the study populations and methodologies diagnosing the carrier state. Since there is not a standard diagnosing method to detect the carrier state as discussed above, it has been postulated that the actual prevalence of AC could be higher than the estimated prevalence [36].

Age

Asymptomatic carriage is mostly seen in children, especially among those between the ages of 4 and 8 years [14–17, 24, 26]. Ive [15] reported that AC rate was inversely proportional to age in 19 carrier (range: 5–15 years), predominantly boys, in Nigeria. However, Neil et al. [25] detected higher mean age rates from 9.2 to 13.3 in age groups that ranged between from 3 and 17 years (mean age: 11), being 73.8% boys and 26.2% girls, in Cape Town, South Africa. Ali-Shtayeh et al. [30] detected 32 carriers, and noted that AC rate was higher in children under 10 years of age compared to those older (0.9% vs. 0.6%), and it was higher in males compared to females (68.8% vs. 31.2%) in the Nablus district of Palestinian Authority.

We recently reported significant age differences between six carriers (10.7 ± 2.3) and four STC cases (8.3 ± 0.5), being all 10 boys and immigrants from the southeastern and eastern regions of Anatolia, Turkey ($P = 0.046$) [35]. This finding also contrasted with that of Figueroa et al. [26] who examined a total of 219 school children, 64.4% boys and 35.6% girls, in the Illubabor district, south-western Ethiopia finding no significant differences in the proportion of possible cases, carriers, and healthy children according to age groups. However, adult carrier state was reported, as will be discussed below [14, 15, 19, 20, 22, 26, 36, 49].

Gender

In literature, it was reported that no correlation was found between gender and presence of keratinophilic fungi among children [14, 24, 26, 34, 36]. However, Reid et al. [50] reported positive scalp cultures

among children in families of the index patients in 47% of the boys and 29% of the girls in Philadelphia, USA. Among adults in those same families 13% of women, and 12% of men had positive scalp cultures. Neil et al. [25] investigated a total of 170 children from each of four geographically distinct child care institutions, between 1 and 17 years (mean: 11 years) of age. They observed that AC was more common in boys (73.8%) than in girls (26.2%) in South Africa.

Ali-Shtayeh et al. [30] demonstrated that carriage rate was higher in boys than in girls (1.0% vs. 0.5%) with a higher proportion of STC cases encountered in boys than in girls (0.4% vs. 0.1%) in school children aged 6–14 years, in Nablus area, Palestine. Abdel-Rahman et al. [10] noted that among the pre-school aged (1–6 years of age) with an equal distribution of gender (212 boys and 234 girls), and mainly black children (85.4%), boys were more likely to be culture-positive (Relative risk (RR) = 1.71), and symptomatic than girls (RR = 1.62) in Kansas City, USA. Recently, we found that boys were more prone to AC ($P = 0.033$), but not to STC ($P > 0.05$) among 10 positive mycologically proven cases, aged between 8 and 14 years, in Adana, Turkey [35]. By contrast, in a study, the AC rate was somewhat higher in girls than in boys (6.1% vs. 4.4%), with a RR of 1.19 ($P = 0.01$) among 56 carriers with a mean age of 6.7 ± 1.9 in southeast London, UK [28].

Also, Sharma et al. [16] investigated 200 preadolescent school-aged children, and indicated that AC ($n = 8$) was more common in girls than in boys (3% vs. 1%) in Kansas City, USA. Interestingly, the authors noted that all of the eight participants involved were black children, with an incidence of 8% in the black population studied. More recently, White et al. [19] examined 209 household contacts (121 adult and 88 children) of 67 patients with *T. tonsurans* STC, 63% of those being of Africo-Caribbean origin and 37% of African origin, in London, UK. The authors observed that children under 16 years of age were much more likely to be carriers compared to adults ($P < 0.001$), and males were less likely to be affected compared to females ($P < 0.01$).

Risk factors

The risk factors for carriage closely parallel those of overt infection. Most cases have been observed in Africo-American [10, 14, 16, 24], Africo-Caribbean [19, 28], African [15, 25, 26], southeast Anatolian immigrant [35], and Arab-originated [36] populations. In one study, the RR of infection was higher among children with Africo-Caribbean hair type (RR = 2.32) compared to a different hair type (RR = 0.05). The RR that a carrier had hair of an Africo-Caribbean style was 1.74 compared to a RR of 0.54 for children with other types [28].

Sharma et al. [16] suggested that the cultural practice of tight braiding and oil-dressing of the hair in young Africo-American girls probably predisposed them to tinea capitis. The authors thought that braiding the hair exposed scalp to pathogens and also dressing the braids with petrolatum, allowed arthroconidia intimate contact with the hair until germination. In contrast, Ghannoum et al. [24] demonstrated that neither hair braiding nor the use of oils or cream rinses were associated with isolation of fungi from the scalp. The authors also stated that the incidence of AC in children had increased in races like Africo-American, the presence of scaling, and the use of anti-dandruff shampoo being important predictors. Honig and Smith [51] suggested fungal infection to be suspected among children with what appears as seborrheic dermatitis or dandruff, and culture to be done in all cases. In fact, tinea capitis should be suspected in all children who do not respond to anti-dandruff shampoo [24].

Age, co-sleeping, comb sharing, and presence of animal pets or domestic animals had no relationship to AC or STC ($P > 0.05$) [14, 36]. However, it has been considered that head-to-head contact, i.e., co-sleeping [14] or the sharing of hair-care products and devices, i.e., comb sharing [14, 36] might be important factors in the transmission of dermatophyte fungi. Midgley and Clayton [13] reported that AC occurred more often in patients with tinea cruris than in those with only foot and/or hand dermatophytosis. Cuétara et al. [23] pointed out that 42% of carriers had also evident ringworm lesions in the other body sites, i.e., tinea faciei and tinea corporis or both.

Katoh et al. [52] examined the scalp of patients with dermatophytosis due to *M. canis* but without scalp lesions, and that of their family members without dermatophytosis. The dermatophytes were detected in 93.8% of the scalps of those who lived in homes where cats were kept, and in 25% of those without cats. To explore the chronicity and

recurrence of tinea cruris, Chakrabarti et al. [53] investigated clinically normal sites like thighs, scrotum, crural cleft, natal cleft, and fourth and fifth toewebs in 49 patients with clinical and mycological confirmation. They isolated dermatophytes in one or more clinically normal sites in 23 (46%) patients at the first visit, and in five (21%) patients in the follow-up survey after 6 months.

Ways of spread

It is clear that to better control the spread of the carrier state, we need to know more about its epidemiology [14]. However, ways of spreading are not clear [48]. It is argued whether spread of anthropophilic infections is based on spread in schools, in the household or on the use of common barbers [38, 54]. There is certainly ample evidence that there is massive contamination of schoolrooms by viable spores in classes where cases have occurred [12]. Hay et al. [28] showed a relation between the risk of infection and carriage in classes, which supports school spreading. However, a number of other studies show a different mechanism for the spread at home environment, which is rather important [14, 19, 21, 55]. Vargo and Cohen [21] highlighted household spread as the most likely way of transmission. There is also evidence to show that in closed communities *T. tonsurans* infection in other skin sites can spread with ease [14].

Also, the increasing incidence of *T. tonsurans* in several countries—USA, Australia, Spain, and UK—has been explained through the persistence of infectious fungal elements on fomites [13, 22, 56]. Mackenzie [12] also noted that extrahuman sources were important in transmission of the organism, in addition to direct transfer. The role of the inanimate sources in maintaining and disseminating infection is difficult to evaluate with certainty, but their importance may be connected with the establishment of a high infection potential. Dermatophytes were isolated from the floor, dust, air, soiled linen, clothing, and curtains [2, 12, 22]. Shared facilities and objects (back of chairs, couches, pillows, rugs, and beds) may also promote the spread of dermatophytes in the classroom and home. Consequently, environmental study is one of the important methods to detect and eradicate dermatophytes [46]. It should be performed in both schools and home environment [22]. The washable items, i.e., bedding and textiles should be laundered, vacuum carried out, and floor mopped with a strong disinfectant. Also, brushes and combes as well as other barbershop tools should be disinfected after use or discarded [2, 22, 56, 57].

The 2007 German-Speaking Mycological Society guideline noted that it is very important to have pets examined very throughly by a veterinarian with mycological experience in case of contact with carriers and/or infection. Pets with either carrier state or dermatophytosis should receive systemic treatment. If the family pets (cats, dogs, rats, mice, guinea-pigs, hamsters, rabbits, etc.) have documented fungal contamination and/or disease, i.e., zoophilic *T. mentagrophytes*, their utensils and potentially contaminated cushions, baskets, blankets, etc. need to be disinfected or discarded [57].

School environment

Midgley and Clayton [13] reported that AC in classes with clinical cases (6.5%–31%) was higher than (0.4%–8.8%) in classes with no cases. The authors also noted that the prevalence of the carrier state in the classroom decreased when the index case of STC was removed from the classroom. There may be an increased frequency of transmission of conidia in children in the lower age groups where there is a greater degree of physical contact. A community point-prevalence study from London, UK, suggested a STC prevalence of about 2.5% (range 0%–12%) with a carriage rate of 4.9% (range 0%–47%) [28].

In contrast to the some other reports [12, 13, 28], as discussed above, Williams et al. [17] found no relation between the development of the carrier state in classrooms that had a clinical case of STC, and those which did not. Cuétara et al. [23] also noted that AC rates within schools were not significantly linked to STC rates. Some later studies reported that carriers as well as index cases were from different classes [30, 35]. These data suggest that index cases were not the primary means of transmission of spores to individuals within classroom [30].

Households

The most common place for close prolonged contact is the household setting. It is where sharing of combs,

brushes, hats, clothing, furniture, toys, and bed linens occurs [46]. It appears that the majority of these household members with AC are children [19–21, 50]. The rates of adult carriage may be consequence of, rather than the cause of higher infection rates [14, 19–21, 36]. Asymptomatic carriage has also been demonstrated in adults and children living with an index case of STC [12, 14, 15, 19–22, 25, 26, 36, 49, 50, 58]. In some studies, it was indicated that the family home might be an even more important source of infection than the schools [20, 22, 58]. Household crowding does not appear to be predictive of either infection or carriage, but family members of those infected with tinea capitis certainly have a higher risk of infection than members of the community at large [21].

Household contacts of patients already diagnosed with STC have been widely discussed in literature [14, 19–21, 36, 58]. A study by Vargo and Cohen [21] including both children and adults ($n = 67$) reported 63% of child contacts to be positive for dermatophyte with only 5% of adults similarly positive. The authors suggested that all household members should be cultured regardless of the presence or absence of clinical findings or subjective complaints. They also noted the prevalence of tinea capitis in family contacts as 3.5 times higher than in the control group ($P > 0.005$). When comparison was restricted to school age children, tinea capitis was 9.4 times more common in siblings of patients with tinea capitis than in control children ($P > 0.001$). In the above cited study by White et al. [19], tinea corporis was observed in 15 of 209 (7.4%) household contacts with six (6.8%) among children and nine (7.4%) among adults, while carrier state was observed in 93 (44.5%) with 56 (63.6%) of children and 37 (30.6%) of adults.

Pomeranz et al. [14] demonstrated 16% overall carriage in adult and child contacts ($n = 114$). Babel and Baughman [20] examined adult household contacts ($n = 46$) and found AC related *T. tonsurans* in 30.4% scalps despite no evidence of disease. The authors also noted that the majority of the adults studied were women (92.9%), because most pediatric patients were accompanied at the clinic visits by their mothers or grandmothers. In line with this report, Akbaba et al. [36] screened households ($n = 32$) of 21 carriers and were able to detect the carrier state in three mothers and one sister, resulting in a total of four households (12.5%). Barlow and Saxe [58] studied asymptomatic adults contacts ($n = 26$) of children with STC, and five (19.2%) female carriers were diagnosed with *T. violaceum*.

In one study, it was reported that household women and girls have higher rates of AC than men or boys. The most likely explanation in adult males is that they may have spent less time overall with their children than women, thereby reducing the risk of transmission. Other mechanism such as fungistatic fatty acids in adult scalp sebum may also explain the lower carriage rates in adults [19]. More recently, in a study conducted by Akbaba et al. [36] school environment and household setting were not found to be a source of transmission. The authors noted that isolation of zoophilic *T. mentagrophytes* from other household members, albeit from asymptomatic carriers, would suggest that these individuals were exposed to the same source of infection, i.e., an infected animal, and person-to-person transmission of zoophilic dermatophytes, though not being common.

Treatment

There is no agreement on whether carriers should be treated with topical antifungal shampoos [14, 20, 23, 25] or systemic antifungals [21, 30, 56] or with both [12, 15] or with neither [18, 19, 35]. In those with moderate or heavy growth of culture, oral therapy may be justified as these individuals are especially likely to develop an overt clinical infection [19, 28] and are unlikely to respond to therapy alone [13]. However, for those with low spore counts on culture, twice weekly selenium sulphide [59] or povidone-iodine (PI) [25] shampoo is probably adequate to impede viable fungi from scalp. Cuétara et al. [22] treated the carriers with ketoconazole shampoo twice weekly for up to 3 months until they achieved fungal eradication in an attempt to reduce potential transmission.

In a study by Neil et al. [25], the authors compared four shampoos; 1% econazole nitrate, 2.5% selenium sulphide, 4% PI, and Johnson's Baby Shampoo, applied twice weekly for 15 min. PI was significantly more effective than the other shampoos, including baby shampoo, with a response rate of 50%. Although this study may imply that PI may be the preferable topical medication for treating the carrier state in the

long-term, it still remains unknown whether the responses with *T. tonsurans* or other species would be similar to those seen with *T. violaceum*, the organism responsible for carrier state.

However, in some other reports, the policy was to treat all individuals with positive cultures from the scalp with oral antifungal agents [21, 56]. Mackenzie et al. [12] reported that after griseofulvin and topical 'bynamid' administration children who were apparently free from infection were followed-up at 3 and 6 months intervals, and the eradication of the fungus was achieved at sixth month. The authors reported that failure to eliminate all infection is attributed to the difficulty of clinical detection. Ive [15] also noted that griseofulvin administration did not appear to influence the rate of clearing in persistent carriers. Ghannoum et al. [24] evaluated the antifungal susceptibility of the *T. tonsurans* isolates recovered from scalp carriers against griseofulvin, fluconazole, itraconazole and terbinafine, and found these strains to be susceptible. More recently, however, Sancak et al. [60] investigated the sensitivity to ketoconazole, itraconazole and terbinafine of dermatophytes isolated from clinical samples finding the highest MIC values among samples with *T. mentagrophytes* related with AC.

Follow-up: why and how?

Follow-up the carriers monthly is recommended until mycological clearence is documented. Vargo and Cohen [21] reported that an individual with a persistent carriage could be a source of infection and/or re-infection for all classmates; that is why it is necessary that a consistent follow-up should be performed. This is also true for household members. But it should be kept in mind that the follow-up requires financial support and cooperation between academicians, clinicians, and mycologists, possibly in coordination of epidemiologists and public health practitioners.

However, it is not clear what the long-term clinical implications would be for AC, since studies that have prospectively evaluated the long-term follow-ups are limited [15–17, 25, 34, 35]. Moreover, Williams et al. [17] found that among their untreated carriers with a mean of 2.3 months of follow-up, 4% became overtly symptomatic, 58% remained culture-positive and 38% became culture-negative. The authors also suggested that these carriers played a role in the transmission of STC within the school population, and also noted that most of those with spontaneous clearing had spore loads of <10.

Ive [15] followed 19 carriers of *M. audouinii*, noting that after 4 months 21% became symptomatic, 42% had persistent carriage and 37% became culture-negative. Neil et al. [25] noted persistent carriage of *T. violaceum* in 25% of carriers followed for 6 weeks to 6 months. The authors also described that griseofulvin administration did not appear to influence the rate of clearing in persistent carriers. Sharma et al. [16] followed six of the eight carriers for a period of 4–10 months, and detected that five were culture-negative; however, one child was still asymptomatic after 4 months and the culture yielded *T. tonsurans.* Polonelli et al. [34] followed two carriers in whom *T. interdigitale* and *M. canis* were isolated, without treatment, and noted that these carriers became culture-negative one year later. In a recent study, the follow-up of carriers for 3–8 months without treatment revealed that the carrier state had disappeared with none of the cases developing clinical lesions [35]. As a result, the approximate percentage of those with positive-cultures who become infected over a 6 month period was found to be about 10% [38].

Conclusion

Tinea capitis as well as AC is still a persistent public health problem all over the world. Asymptomatic scalp carriage, however, assissted us in better understanding the pathogenesis of STC, and demonstrated a new pattern of infection with public health implications. Present available literature data reveals that AC is mostly related to anthropophilic species, and principally to *T. tonsurans* and *T. violaceum*. However, predominant isolation of zoophilic species, *M. canis*, and *T. mentagrophytes*, were also reported. It is now clear that AC is not uncommon in childhood and presumed capable of transmitting infection by shedding viable fungal propagules. On the other hand, the challenge still remains to determine the gold standard method for detecting the carrier state.

The first thing to do in management of AC is detecting spore load. This will provide us a perspective

to develop regarding the contagiousity and the management of treatment. Additionally, information about carrier's environment, as well as research including classmates and playmates, may aid us in controlling the spread of fungi. On the other hand, children's scalp should be routinely inspected at school as well as good hygiene, and sharing of hats, scarves, combs and hairbrushes must be avoided. In order to combat AC, public education is required in addition to taking general sanitation measures.

As was stated by Hay et al. [28] interdisciplinary collaboration among mycologist, dermatologist, general practitioners, veterinarians as well as public health and school health authorities is necessary to ensure the identification of new cases and the prompt and appropriate treatment. Another, maybe more practicle approach could be the integration of these interventions into the school health programs in which AC and STC consist an important fraction among infectious diseases. Perhaps this will also reveal both financial and organizational obstacles regarding the subject, taking into account the advantage of preventive medicine in comparison to curative medicine, in addition to the long-term character of school health programs.

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