



Tinea Capitis in Children Younger than Two Years Old: A Retrospective Study and Treatment Recommendations

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Abstract

Background Tinea capitis (TC) is a dermatophytosis of the scalp and hair, which occurs less common in children younger than two years of age, and the data of TC in this age group are still unknown.

Objectives We aimed to reveal the epidemiological, clinical and mycological characteristics of TC in children under two years old.

Methods We retrospectively analyzed all reported cases of TC in children in their first two years of life

from 1991 to 2022, by searching PubMed, Embase, Web of Science, CNKI, Wanfang and Weipu databases.

Results A total of 47 articles involving 126 cases of pediatric TC were enrolled in this study. The sex ratio (M/F) was 1.28:1. The age of the children ranged from ten days old to two years old with a median age of three months. The main clinical manifestations were alopecic patches (40 cases, 31.7%) and scaling (39 cases, 31.0%) on the scalp, and 29 infants (23.0%) appeared kerion. The most common sources of contagion were animals (35 cases, 27.78%) and humans (31 cases, 24.60%). The leading pathogens were *Microsporidium canis* (64 cases, 50.79%), followed by *Trichophyton violaceum* (13 cases, 10.32%), *T. mentagrophytes complex* (12 cases, 9.52%) and *T. tonsurans* (10 cases, 7.94%). Ninety-five children (75.40%) were treated with systemic antifungal drugs and 22 patients (17.46%) were only treated with topical therapy. Except for 10 patients with unknown final prognosis, all the other cases were cured after treatment. There was one child (0.79%) relapsed after treatment with griseofulvin and one case (0.79%) presented with gastrointestinal symptoms from griseofulvin.

Conclusion The principal clinical symptoms of TC in children less than two years old were alopecic patches and scaling. The top four pathogens were *M. canis*, *T. violaceum*, *T. mentagrophytes complex* and *T. tonsurans*. Oral treatment for pediatric TC had

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achieved good therapeutic effects, and topical therapy can be an alternative choice.

Keywords Dermatophytosis · Dermatophyte · Tinea capitis · Children younger than two years old

Introduction

Tinea capitis (TC) is a dermatophyte infection of the scalp and hair that appears most common in children, especially preschool children between 3 and 7 years old [1]. It rarely occurs in children in their first two years of life, and there are only a few literatures reporting this age group population and most of them are case reports [2, 3]. Therefore, the epidemiological, clinical and mycological characteristics of pediatric TC in children less than two years old are still unknown. Clinically, pediatric TC can vary considerably, including scaling, annular erythema, alopecia, broken hairs or even kerion, which often leads to misdiagnosis, such as seborrheic dermatitis, neonatal lupus erythematosus, impetigo or atopic dermatitis [4, 5]. If the diagnosis and treatment are not timely, it will cause serious consequences, and even permanent hair loss. Systemic antifungal therapy is the standard for TC, however, for a majority of countries there has been no Food and Drug Administration (FDA) approved oral drugs for the children under two years old [6]. In addition, there is still a lack of research or guidelines for what kind of therapy should be recommended in this age group, which limits clinical treatment. In this study, we systematically reviewed all literatures and summarized the epidemiology, clinical features, pathogens and treatment strategies of TC in children younger than two years old, in order to provide effective information and recommendations on the treatment for clinicians.

Methods

We reviewed all cases in children less than two years of age with an established diagnosis of TC from 1991 to 2022 (32 years), using the key search terms (“tinea capitis” OR “kerion” OR “favus”) AND (“children” OR “infant” OR “newborn” OR “neonate” OR “pediatric” OR “younger than two years old”). A

search for all studies (case reports, case series, retrospective or prospective trials) were performed in the following foreign and domestic databases: PubMed, Embase, Web of Science, CNKI (<http://www.cnki.net/>), WanFang (<http://www.wanfangdata.com.cn/>) and WeiPu (<http://www.cqvip.com/>). Titles and abstracts from initial search were reviewed. Inclusion criteria were as follows: (i) studies published in either English or Chinese; (ii) articles published from 1991 to 2022; (iii) included patients’ age under 2 years old; (vi) established diagnosis of TC. The remaining studies were reviewed in detail and studies with obvious wrong or unclear records of data were excluded. Data on demographics, source of contagion, clinical presentation, pathogen, treatment, drug safety and prognosis were extracted from qualified studies and were analyzed using descriptive statistics.

Results

A total of 651 articles were retrieved by using the key search terms, and 47 articles were qualified according to the inclusion and exclusion criteria. One hundred and twenty-six cases of TC in children less than 2 years old from 14 countries were included and analyzed (Tables 1 and 2).

Epidemiological Features

Males (68 cases, 56.20%) of pediatric TC were slightly higher than females (53 cases, 43.80%) with a sex ratio (M/F) of 1.28:1. The other nine patients’ gender information were not available in the literatures. The patients’ age ranged from 10 days old to 2 years old with a median age of 3 months, among them, children younger than 6 months old accounted for the highest proportion of 46.03% (Fig. 1). The duration of the disease prior to diagnosis ranged from 3 to 270 days (median = 30 days). A total of 30 cases (23.8%) had a clear history of misdiagnosis as seborrheic dermatitis, eczema, impetigo or neonatal lupus, treated with topical steroid cream (13 cases) and systemic or topical antibiotics (12 cases), which aggravated the lesions and even evolved into kerion. Animals (35 cases, 27.78%) were the most common source of contagion, followed by humans (31 cases), accounting for 24.60% (Fig. 2).

Table 1 Data on demographics, source of contagion, clinical presentation and pathogen of tinea capitis in children younger than two years old

No	Author	Country	Report year	Cases number	Sex	Age	Diagnosis time (day)	Misdiagnosis	Source of contagion	Clinical presentation	Pathogen
1	Gondim-Gonçalves [7]	Brazil	1992	1	M	90d	74	NA	Mother	Erythematous, scaly plaque	<i>M. canis</i>
2	Snider [8]	USA	1993	4	F	19d	NA	NA	A nurse	Erythematous, scaly plaque	<i>M. canis</i>
					F	16d	NA	NA	A nurse	Annular dry, flaky patch	<i>M. canis</i>
					M	75d	NA	NA	A nurse	Alopecic patches	<i>M. canis</i>
					F	31d	NA	NA	A nurse	Erythematous, scaly plaque	<i>M. canis</i>
3	Virgili [9]	Italy	1993	2	NA	43d	5–20	NA	Mothers and/or brothers or sisters	Seborrheic dermatitis-like scaling	<i>M. canis</i>
					NA	25d		NA	Mothers and/or brothers or sisters	Seborrheic dermatitis-like scaling	<i>M. canis</i>
4	Cabon [10]	France	1994	2	NA	10d	NA	NA	Mother	Seborrheic dermatitis-like scaling	<i>M. langeronii</i>
					NA	21d	NA	NA	Mother	Seborrheic dermatitis-like scaling	<i>M. langeronii</i>
5	Ghorpade [11]	India	1994	1	M	10d	4	NA	Not identified	Black-dot tinea	<i>T. violaceum</i>
6	García-Sánchez [12]	Spain	1997	1	M	22 m	14	Topical antibiotic and corticosteroid cream	Suspected rabbit	Favus	<i>T. mentagrophytes</i> var. <i>quinckeianum</i>
7	Ungar [13]	USA	1997	1	M	19d	4	No	Not identified	An alopecic patch	<i>T. rubrum</i> + <i>T. mentagrophytes</i>
8	Weston [14]	USA	1998	1	NA	5w	21	Oral and intravenous antibiotics	Not identified	Kerion	<i>T. tonsurans</i>
9	Wilmer [15]	Germany	1998	1	F	10 m	42	No	NA	Kerion	<i>T. mentagrophytes</i>
10	Romano [16]	Italy	1999	1	F	20 m	90	Systemic and topical antibiotics	Human (grecche)	Kerion	<i>T. rubrum</i>
11	Ginarte [17]	Spain	2000	1	F	2y	42	Topical ketoconazole without success	Not identified	Sticky scales	<i>M. canis</i>
12	Koumantaki [18]	Greece	2001	1	F	8 m	60	Impetigo	Suspected cat	Kerion	<i>M. canis</i>

Table 1 continued

No	Author	Country	Report year	Cases number	Sex	Age	Diagnosis time (day)	Misdiagnosis	Source of contagion	Clinical presentation	Pathogen
13	Romano [19]	Italy	2001	15	F	10 m	NA	Five of the 15 patients were misdiagnosed	Cat	Microsporium scalp ringworm	<i>M. canis</i>
					M	6 m			Human (orphanage)	Trichophyton scalp ringworm	<i>T. violaceum</i>
					M	12 m			Cat	Microsporium scalp ringworm	<i>M. canis</i>
					M	8 m			Cat	Microsporium scalp ringworm	<i>M. canis</i>
					M	2 m			Cat	Microsporium scalp ringworm	<i>M. canis</i>
					F	1 m			Cat	Microsporium scalp ringworm	<i>M. canis</i>
					M	6 m			Sister	Trichophyton scalp ringworm	<i>T. tonsurans</i>
					M	8 m			Human	Kerion	<i>T. mentagrophytes</i>
					M	1.5 m			Cat	Microsporium scalp ringworm	<i>M. canis</i>
					M	11 m			Cat	Microsporium scalp ringworm	<i>M. canis</i>
					M	2.5 m			Cat	Microsporium scalp ringworm	<i>M. canis</i>
					F	1.5 m			Cat	Microsporium scalp ringworm	<i>M. canis</i>
					F	10 m			Cat	Kerion	<i>T. mentagrophytes</i>
					F	3 m			Not identified	Trichophyton scalp ringworm	<i>T. mentagrophytes</i>
14	Chang [20]	Korea	2002	1	M	10 m			Soil	Kerion	<i>T. erinacei</i>
					M	4w	9		Father	Oozing and scaly patch	<i>T. rubrum</i>
15	Gilaberte [21]	Spain	2003	1	M	4 m	120	NA	Mother	Two scaly alopecic patches	<i>M. audouinii</i>
16	Aste [22]	Italy	2004	1	F	40d	14	Bacterial infection with oral and topical antibiotics	Parents	Kerion	<i>M. canis</i>

Table 1 continued

No	Author	Country	Report year	Cases number	Sex	Age	Diagnosis time (day)	Misdiagnosis	Source of contagion	Clinical presentation	Pathogen
17	Gilaberte [23]	Spain	2004	10	M	1.5 m	NA		Not identified	Three sealy alopecic patches	<i>M. audouinii</i>
					M	4 m			Mother and brother	Two sealy alopecic patches	<i>M. audouinii</i>
					F	12 m			Not identified	Alopecic patches	<i>T. verrucosum</i>
					F	12 m			Not identified	Three sealy alopecic patches	<i>M. canis</i>
					F	3 m			Cat	Sealy alopecic patches	<i>M. canis</i>
					F	3 m			Cat and rabbits	Two circinate lesions	<i>M. canis</i>
					M	11 m			Not identified	Sealy erythematous alopecic plaque	<i>M. canis</i>
					M	11 m			Brother	Two alopecic patches	<i>T. tonsurans</i>
					M	10 m			Cat	Sealy alopecic patches	<i>T. tonsurans</i>
					M	11 m			African immigrants	Sealy alopecic patches	<i>M. audouinii</i>
18	Valari [24]	Greece	2006	1	F	3 m	35	No	Mother	Sealy alopecic patches	<i>T. rubrum</i>
19	Binder [25]	Austria	2009	7	F	46w	NA	NA	NA	Scaling, hair loss	<i>M. canis</i>
					F	44w	NA	NA	NA	Erythema, scaling hair loss	<i>M. canis</i>
					F	3w	NA	NA	NA	Erythema, patches	<i>M. canis</i>
					M	8w	NA	NA	NA	Hair loss	<i>M. canis</i>
					F	32w	NA	NA	NA	Scaling, erythema	<i>M. canis</i>
					M	36w	NA	NA	NA	Scaling, hair loss	<i>M. canis</i>
					F	4w	NA	NA	NA	Erythema, scaling	<i>M. canis</i>
20	Larralde [26]	Argentina	2010	3	M	55d	41	NA	Rabbit	Kerion	<i>T. mentagrophytes</i> var. <i>mentagrophytes</i>
					F	20d	7	NA	Father	Kerion	<i>T. rubrum</i>
					M	4w	7	NA	Rabbit	Kerion	<i>T. mentagrophytes</i> var. <i>mentagrophytes</i>
21	Atanasovski [27]	USA	2011	1	F	3w	7	Neonatal lupus	Not identified	Erythema, scaling hair loss	<i>M. canis</i>
22	Mapelli [28]	Italy	2012	1	F	15d	8	Seborrheic dermatitis and local steroids	Mother	A sealy patch	<i>T. rubrum</i>

Table 1 continued

No	Author	Country	Report year	Cases number	Sex	Age	Diagnosis time (day)	Misdiagnosis	Source of contagion	Clinical presentation	Pathogen
23	Michaels [4]	USA	2012	1	F	8 m	210	Topical corticosteroid cream	Cat	Erythema, scaling	<i>M. canis</i>
24	Zaraa [29]	Tunisia	2012	35	M	0–6 m	Average 31	Cat 6	Alopecic patches 17	<i>M. canis</i> 18	
					F 14	6–12 m	2	Dog 2	Diffuse scaling 13	<i>T. violaceum</i> 9	
						12–18 m	5	Rabbit 1	kerion 5	<i>T. verrucosum</i> 1	
						18–24 m	27	Family members 2	<i>T. mentagrophytes</i> 1		
25	Ambooken [30]	India	2013	1	M	3 m	60	Systemic antibiotics and a steroid-antibiotic cream	Mother	Kerion	<i>M. gypseum</i> (Nannizzia gypsea)
26	Berry [31]	USA	2014	1	M	21d	7	Neonatal lupus erythematosus and topical corticosteroid cream	NA	Scale, pustules, and erythema	<i>T. tonsurans</i>
27	Huégins [32]	USA	2015	1	M	24d	7	No	NA	Annular plaques	<i>T. tonsurans</i>
28	Zampella [5]	USA	2017	4	F	12 m	NA	Bullous impetigo with oral antibiotics	NA	Annular, scaly, red plaque	<i>M. canis</i>
					M	18d		Seborrheic dermatitis with moisturizers	NA	Erythematous, scaly patches	<i>T. tonsurans</i>
					M	14d		No	NA	Annular plaque	<i>M. canis</i>
					F	16 m		Eczema	NA	Scaly patches, hair loss	<i>T. tonsurans</i>
29	Fremerey [33]	Germany	2018	1	M	3w	14	No	Mother	Kerion	<i>T. soudanense</i>
30	Mandras [2]	Italy	2019	1	M	12 m	NA	NA	Not identified	Erythema, hair loss	<i>M. canis</i>
31	Kumar [34]	India	2021	2	F	10 m	60	NA	Brother	Scaly, erythematous alopecia patch	None
					F	3 m	20	NA	NA	Erythematous scaly alopecic patch	None
32	Toyosawa [3]	Japan	2022	1	F	2y	45	Contact dermatitis with topical steroid	NA	Kerion	<i>N. gypsea</i>
33	Chen [35]	China	2001	1	M	2.5 m	30	Injection of Penicillium	NA	Kerion	<i>M. fuientis</i>
34	Lu [36]	China	2001	1	M	10 m	270	Multiple misdiagnoses	Barber knife	Kerion	<i>T. tonsurans</i> var. <i>tonsurans</i>
35	Zhu [37]	China	2003	1	M	4 m	30	Eczema, impetigo	Mother	Kerion	<i>M. canis</i>
36	Chen [38]	China	2007	1	F	4 m	30	Seborrheic dermatitis	Not identified	Black-dot tinea	<i>T. violaceum</i>
37	Gao [39]	China	2007	1	M	3 m	21	No	Cat	Kerion	<i>M. canis</i>

Table 1 continued

No	Author	Country	Report year	Cases number	Sex	Age	Diagnosis time (day)	Misdiagnosis	Source of contagion	Clinical presentation	Pathogen
38	Xing [40]	China	2009	1	F	8 m	30	Topical steroid cream	Dog	Kerion	<i>T. mentagrophytes</i>
39	Wang [41]	China	2011	3	M	27d	13	No	Brother	Kerion	<i>M canis</i>
					M	17d	10	No	Cat	Kerion	<i>M canis</i>
40	Jing [42]	China	2014	1	F	25d	7	Topical steroid cream	Not identified	Scaling, hair loss	<i>M canis</i>
41	Tang [43]	China	2016	1	M	4 m	30	Topical steroid cream	NA	Kerion	<i>T. mentagrophytes</i>
42	Wang [44]	China	2017	1	M	5 m	90	Oral antibiotics	Not identified	Kerion	<i>T. tonsurans</i>
43	Liu [45]	China	2017	1	M	30d	5	Eczema, impetigo	Grandmother	Kerion	<i>T. mentagrophytes</i>
44	Guo [46]	China	2018	1	F	21d	30	NA	Not identified	Black-dot tinea	<i>T. violaceum</i>
					F	21d	7	Topical cream	NA	Erythematous, scaly patches	<i>M canis</i>
45	Huang [47]	China	2020	1	F	11 m	240	No	Cat	Black-dot tinea	<i>M canis</i>
46	Xiao [48]	China	2021	1	F	23d	3	No	Aunt	Annular erythema	<i>M canis</i>
47	Zhou [49]	China	2022	4	F	7 m	NA	NA	Cat	NA	<i>M canis</i>
					M	22 m	NA	NA	Dog	NA	<i>M canis</i>
					M	2 m	NA	NA	Rabbit	NA	<i>T. mentagrophytes</i>
					M	2 m	NA	NA	Cat	NA	<i>M canis</i>

M male; *F* female; *D* day; *w* week; *m* month; *NA* data not available

Clinical Manifestations and Pathogens

The clinical presentation of pediatric TC was variable, and the main clinical manifestations were alopecic patches (40 cases, 31.7%) and scaling (39 cases, 31.0%) on the scalp. Twenty-nine children (23.0%) appeared follicular pustules with exudative or overlying crust on alopecic patches, suggesting a kerion. Four cases (3.17%) and one case (0.79%) were diagnosed as black-dot tinea and favus due to *T. mentagrophytes* var. *quinckeanum*, respectively. The other thirteen patients' clinical manifestations were not described in detail. There were 12 species of dermatophytes isolated from patients. The most predominant pathogens were *M. canis* (64 cases, 50.79%), followed by *T. violaceum* (13 cases, 10.32%), *T. mentagrophytes* complex (12 cases, 9.52%) and *T. tonsurans* (10 cases, 7.94%). Other strains were only reported in several cases, besides, a case of TC in a newborn was found caused by two organisms, *T. rubrum* and *T. mentagrophytes* complex (Fig. 3).

Treatment and Prognosis

Ninety-five children (75.4%) were treated with systemic antifungal drugs, including 64 patients with griseofulvin, 13 patients with itraconazole, 8 patients with terbinafine, 7 patients with fluconazole, and 3 patients with two oral antifungal drugs for the former one ineffective. Besides, 22 patients (17.46%) were only treated with topical therapy, and 9 patients' treatment strategy were unknown (Fig. 4). Except for 10 patients with unknown final prognosis, all the other cases were cured after treatment and one patient relapsed after treatment with griseofulvin 20 mg/kg/d for two months, who was cured after giving griseofulvin for another one month. There were almost no drug-related side effects except one child (0.79%) presented with gastrointestinal symptoms from griseofulvin, who got better after stopping the drug.

Discussion

We systemically reviewed all articles published in English and Chinese referring to TC in children less than two years old. This study revealed the epidemiological features and treatment recommendations of pediatric TC, providing valuable information for the

diagnosis and treatment of TC in children under two years old.

Overall, the data on TC in this age group are limited because of the unusual and low reported prevalence. Children aged 3 ~ 7 years old remain the most commonly affected [1]. We found that the epidemiology, pathogen spectrum and clinical presentation of TC in children younger than two years old were similar to those older than two years old [50], and different from TC in adults [51]. In infants and children, boys were slightly more susceptible to TC than girls (1.28:1), which may be attributed to boys having short hair, more contact with animals and more outdoor physical activities [52]. We confirmed that the top four pathogens were *M. canis*, *T. violaceum*, *T. mentagrophytes* complex and *T. tonsurans*. The most common zoophilic species were *M. canis*, followed by *T. mentagrophytes* complex, which can cause dermatophytosis in animals, and indirectly infect humans through close contact [53]. The most commonly isolated anthropophilic dermatophytes were *T. violaceum* and *T. tonsurans*, and mothers were the main source of contagion, who acted as symptomatic or asymptomatic carriers of the anthropophilic pathogens. TC may be seen in various clinical presentation, including hair loss, scaling, black dots, follicular pustules and kerions, depending on the species of dermatophytes, the phase of infection and the immune status of the host [54]. The symptoms of TC in children younger than two years old were similar to older children, and alopecic patches and scaling were noted as the most common types. Therefore, the diagnosis of TC should be considered when an infant presents with scaling, alopecic patches or broken hair on the scalp [23].

Historical data revealed that the fungal distribution pattern of TC in children varied in different countries and times [55]. In China, with the development of economy, the improvement of sanitation and social changes, zoophilic fungi (*M. canis*) are gradually replacing anthropophilic fungi (*T. schoenleinii* and *T. violaceum*) as the most prevalent agent of TC [56]. In Central Europe and the Mediterranean countries, pets are becoming the most likely sources of contagion and TC is predominantly due to *M. canis* [57]. Whereas in the USA, France and the UK, due to the increase in the immigration of people with African origin, most cases of TC are caused by *T. tonsurans* [58, 59]. In some Africa areas, TC has always been a serious problem for

Table 2 Data on treatment, drug safety and prognosis of tinea capitis in children younger than two years old

No	Author	Systemic therapy	Duration	Topical therapy	Side effects	Cure	follow-up
1	Gondim-Gonçalves [7]	Griseofulvin 125 mg/d	6w	No	None	Yes	NA
2	Snider [8]	Griseofulvin 15 mg/kg/d	NA	Clotrimazole/econazole	NA	NA	NA
		NA		Clotrimazole/econazole	NA	NA	NA
		NA		Clotrimazole/econazole	NA	NA	NA
		NA		Clotrimazole/econazole	NA	NA	NA
3	Virgili [9]	NA		NA	NA	NA	NA
		NA		NA	NA	NA	NA
4	Cabon [10]	NA		NA	NA	NA	NA
		NA		NA	NA	NA	NA
5	Ghorpade [11]	NA		NA	NA	NA	NA
6	García-Sánchez [12]	Griseofulvin 125 mg/d	NA	Terbinafine cream	None	Yes	Alopecia
7	Ungar [13]	Griseofulvin 15 mg/kg/d	4w	Econazole cream + ketoconazole shampoo	None	Yes	No recurrence
8	Weston [14]	Griseofulvin 20 mg/kg/d	4w	No	None	Yes	NA
9	Wilmer [15]	Griseofulvin 10 mg/kg/d for 4 w (ineffective); terbinafine 62.5 mg/d for 4 w (cure)	4w	Cyclopiroxolamine	None	Yes	Alopecia
10	Romano [16]	Micronized griseofulvin 20–25 mg/kg/d	5w	Imidazoles	None	Yes	No recurrence
11	Ginarte [17]	Griseofulvin 10 mg/kg/d	8w	Salicylic acid ointment	None	Yes	Partial hair loss
12	Koumantaki [18]	Itraconazole 5 mg/kg/d, each of 1 week duration with an interval of 2 weeks	Two pulses	Antifungal shampoo	None	Yes	No recurrence

Table 2 continued

No	Author	Systemic therapy	Duration	Topical therapy	Side effects	Cure	follow-up
13	Romano [19]	Griseofulvin 125 mg/d	40d	Imidazole	None	Yes	NA
		Griseofulvin 125 mg/d	30d	Imidazole	None	Yes	NA
		Griseofulvin 125 mg/d	2 m	Imidazole	None	Yes	NA
		Griseofulvin 125 mg/d	20d	Imidazole	None	Yes	NA
		Griseofulvin 125 mg/d	30d	Imidazole	None	Yes	NA
		Terbinafine 52.5 mg/d	3w	No	None	Yes	NA
		Terbinafine 52.5 mg/d	4w	No	None	Yes	NA
		Griseofulvin 125 mg/d	45d	Imidazole	None	Yes	NA
		Griseofulvin 125 mg/d	2w	Imidazole	None	Yes	NA
		Griseofulvin 125 mg/d	2 m	Imidazole	None	Yes	NA
		Griseofulvin 125 mg/d	3w	Imidazole	None	Yes	NA
		Griseofulvin 125 mg/d	2.5w	Imidazole	None	Yes	NA
		Griseofulvin 125 mg/d	50d	Imidazole	None	Yes	NA
		Griseofulvin 125 mg/d	4w	Imidazole	None	Yes	NA
		Griseofulvin 125 mg bid	60d	Imidazole	None	Yes	NA
14	Chang [20]	Itraconazole solution 25 mg/2.5 ml/d, each pulse lasting 1 week, with 2 weeks off drug between the first and second pulses and 3 weeks off between the second and third pulses	Three pulses	ketoconazole shampoo qod × 2 m	None	Yes	No recurrence
15	Gilaberte [21]	Griseofulvine 15 mg/kg/d	8w	ketoconazole 2% shampoo	None	Yes	NA
16	Aste [22]	Terbinafina 62.5 mg/d	1 m	No	None	Yes	No recurrence

Table 2 continued

No	Author	Systemic therapy	Duration	Topical therapy	Side effects	Cure	follow-up
17	Gilaberte [23]	Fluconazole (ineffective); Griseofulvin 15 mg/kg/d × 45–60 days (cure) Griseofulvin 15 mg/kg/d Griseofulvin 15 mg/kg/d No No Griseofulvin 15 mg/kg/d No Griseofulvin 15 mg/kg/d × 45–60 days Griseofulvin 15 mg/kg/d × 45–60 days No	45–60d 45–60d 45–60d 45–60d 45–60d 45–60d	No No No Terbinafine cream Ketoconazole cream No Ketoconazole gel No No Ciclopiroxol cream (ineffective); Terbinafine cream	None None None None None None None None None	Yes Yes Yes Yes Yes Yes Yes Yes Yes	No recurrence No recurrence No recurrence No recurrence No recurrence NA NA No recurrence No recurrence No recurrence
18	Valari [24]	Fluconazole 6 mg/kg/d	3w	0.25% amorolfine cream	None	Yes	No recurrence
19	Binder [25]	Itraconazole 5 mg/kg/d Itraconazole 5 mg/kg/d Itraconazole 5 mg/kg/d Itraconazole 5 mg/kg/d Itraconazole 5 mg/kg/d Itraconazole 5 mg/kg/d	3 s 4w 6w 3w 4w 6w 4w	Antimycotic shampoo and azoles cream Antimycotic shampoo and azoles cream Antimycotic shampoo and azoles cream Antimycotic shampoo and azoles cream Antimycotic shampoo and azoles cream	None None None None None None	Yes Yes Yes Yes Yes Yes	No recurrence No recurrence No recurrence No recurrence No recurrence No recurrence
20	Larralde [26]	Griseofulvin 20 mg/kg/d	45d	No	None	Yes	NA
21	Atanasovski [27]	No Fluconazole 5 mg/kg/d Griseofulvin 20 mg/kg/d	4w 3w	Imidazole × 2 m No Ketoconazole 2% shampoo × 3 ^w	None None None	Yes Yes Yes	NA NA NA
22	Mapelli [28]	No		Econazole nitrate 1% cream × 1 m	None	Yes	No recurrence

Table 2 continued

No	Author	Systemic therapy	Duration	Topical therapy	Side effects	Cure	follow-up
23	Michaels [4]	Griseofulvin suspension 25 mg/kg/d	8w	Ciclopirox 1% shampoo × 8w	None	Yes	NA
24	Zaraa [29]	Griseofulvin 15 mg/kg/d for all infants except five (less than 6 months of age)	6–12w	Antifungal topicals	None	Yes	2 cases of kerion showed persistent alopecia
25	Ambooken [30]	Ultra-micronized griseofulvin 10 mg/kg/d	6w	No	None	Yes	No recurrence
26	Berry [31]	Griseofulvin	6w	No	None	Yes	NA
27	Hudgins [32]	NA	6w	NA	NA	NA	NA
28	Zampella [5]	Fluconazole 5 mg/kg/d	6w	No	None	Yes	No recurrence
		Fluconazole 5 mg/kg/d	6w	No	None	Yes	NA
		Griseofulvin 15 mg/kg/d	10w	No	None	Yes	No recurrence
		Griseofulvin × 4 w (ineffective); terbinafine 125 mg/d × 6w (cure)	6w	No	Gastrointestinal symptoms from griseofulvin, none with terbinafine	Yes	No recurrence
29	Fremery [33]	Intravenous fluconazole × 1w + oral fluconazole × 2w	3w	Clotrimazole and octenidine	None	Yes	NA
30	Mandras [2]	Griseofulvin 20 mg/kg/d	2 m	Tioconazole cream	None	Yes	Recurrence at 15 days later at the end of treatment, griseofulvin 20 mg/kg/d × 1 m
31	Kumar [34]	Fluconazole 30 mg twice a week	8w	2% miconazole cream	None	Yes	No recurrence
		Fluconazole 20 mg twice a week	6w	Ketoconazole shampoo	None	Yes	No recurrence
32	Toyosawa [3]	No		Luliconazole cream × 2w	None	Yes	Scarring alopecia
33	Chen [35]	No		clotrimazole cream + terbinafine cream × 6w	None	Yes	No recurrence
34	Lu [36]	Terbinafine 62.5 mg/d	8w	Sulphur ointment	None	Yes	No recurrence
35	Zhu [37]	Itraconazole 20 mg/d	5d	Sulphur ointment × 3w	None	Yes	No recurrence
36	Chen [38]	No		ketoconazole shampoo + Sertaconazole and bifenazole cream for 1 m	None	Yes	NA
37	Gao [39]	No		Miconazole nitrate cream bid × 6w	None	Yes	No recurrence

Table 2 continued

No	Author	Systemic therapy	Duration	Topical therapy	Side effects	Cure	follow-up
38	Xing [40]	Griseofulvin 15 mg/kg/d	2w	5% Sulphur ointment bid × 8w	None	Yes	NA
39	Wang [41]	No		Bifonazole cream × 21d	None	Yes	No recurrence
		No		Compound benzoic acid cream + compound ketoconazole cream × 21d	None	Yes	No recurrence
		No		Compound benzoic acid cream + compound ketoconazole cream × 21d	None	Yes	No recurrence
40	Jing [42]	Itraconazole 5 mg/kg/d	6w	Terbinafine cream bid × 6 w	None	Yes	NA
41	Tang [43]	Itraconazole 33 mg/d	9w	2% ketoconazole shampoo + 1% naftifine + 0.25% ketoconazole cream	None	Yes	No recurrence
42	Wang [44]	No		Naftifine hydrochloride and ketoconazole Cream bid × 20d	None	Yes	NA
43	Liu [45]	No		Miconazole nitrate cream bid × 3 m	None	Yes	No recurrence
44	Guo [46]	No		Sertaconazole nitrate cream and terbinafine hydrochloride twice a day for 7 days	None	Yes	NA
45	Huang [47]	No		Terbinafine cream bid × 1 m	None	Yes	NA
46	Xiao [48]	Itraconazole oral solution (5 mg/kg/d, first pulse 2.3 ml/d, second pulse 3 ml/d) pulse therapy (1 week on active treatment and 3 weeks off drug)	Two pulses	Terbinafine cream × 8 w	None	Yes	No recurrence
47	Zhou [49]	Terbinafine 10 mg/kg/d	8w	Terbinafine cream bid + topical steroid cream qd	None	Yes	No recurrence
		Terbinafine 10 mg/kg/d	8w	Terbinafine cream bid	None	Yes	No recurrence
		Terbinafine 10 mg/kg/d	8w	Terbinafine cream bid	None	Yes	No recurrence
		Terbinafine 10 mg/kg/d	6w	Terbinafine cream bid + topical steroid cream qd	None	Yes	No recurrence

D day; w week; m month; NA data not available

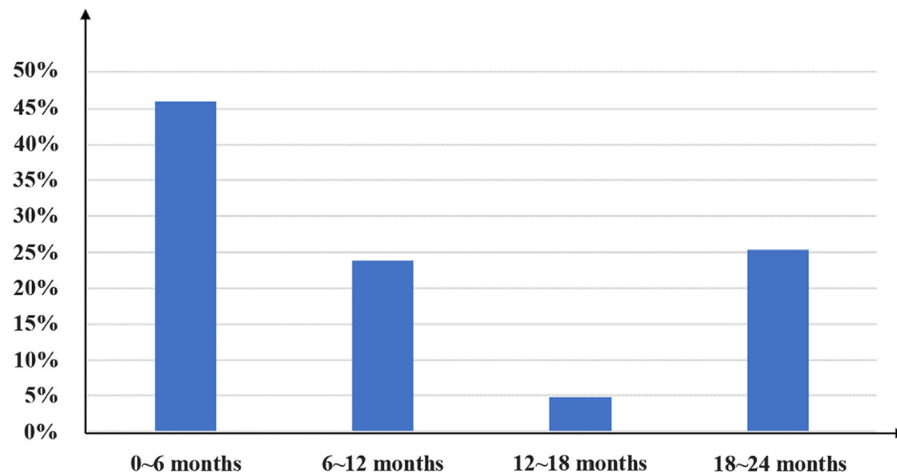


Fig. 1 Age distribution of tinea capitis in children younger than two years old

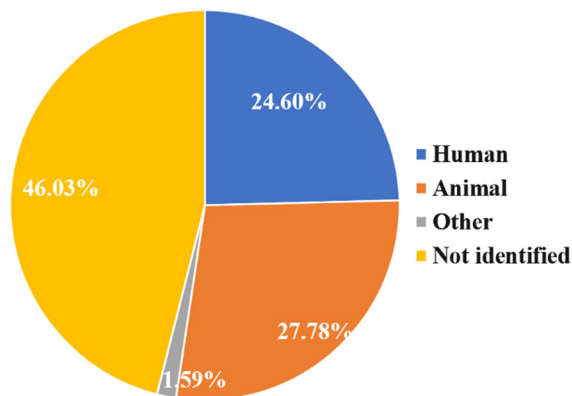


Fig. 2 Source of contagion of tinea capitis in children less than two years old

the poor hygiene and socioeconomic conditions, and dermatophytes with partial geographical restriction, like *T. violaceum* and *T. sudanense*, were the leading pathogens [60, 61]. In our study, for the limited cases of TC in younger children, we didn't find the significant differences in fungal profiles across countries and regions.

Clinically, systemic antifungal drugs have always been recommended for the successful treatment of TC. Since 1959, griseofulvin remains the gold standard of systemic therapy for TC, but high doses and long treatment periods are warranted [62]. The newer antifungal agents terbinafine, itraconazole and fluconazole are now being used more frequently for TC especially in children older than 2 years old, with good

efficacy and safety but a reduced treatment duration [6, 63]. However, for the majority of countries in the world, there are still no FDA approved oral agents or treatment guidelines of TC for the children less than two years of age [64]. Till now, there is controversy on whether systemic or topical treatment should be used for TC in this age group. There are mainly two sides of cautious. For one hand, systemic therapy is an off-label treatment, and drug risks limit the use of oral drugs. For the other hand, although topical therapy is felt to be safer for infants, TC usually causes infection at the root of the hair follicle deep within the dermis, and topical treatment alone cannot completely clear the fungus, resulting in higher recurrence rates. In our literature review, we noted that both oral and topical drugs have achieved good therapeutic effects, and almost no reported side effects and recurrence were noted during the whole treatment period and follow up. Besides, Chen et al. [65] found that oral itraconazole was safe and effective in infants and the profiles of adverse events were similar to those in adults and older children through a retrospective analysis of a large number of articles. These results remind us oral antifungal drugs, including griseofulvin, itraconazole, terbinafine and fluconazole, have few adverse effects and topical treatment can be an alternative choice, furthermore, the issues of drug safety and recurrence are not as many as we worried about.

Here, we give the following treatment recommendation for pediatric TC in children under two years old according to these acquired data: (i) children with

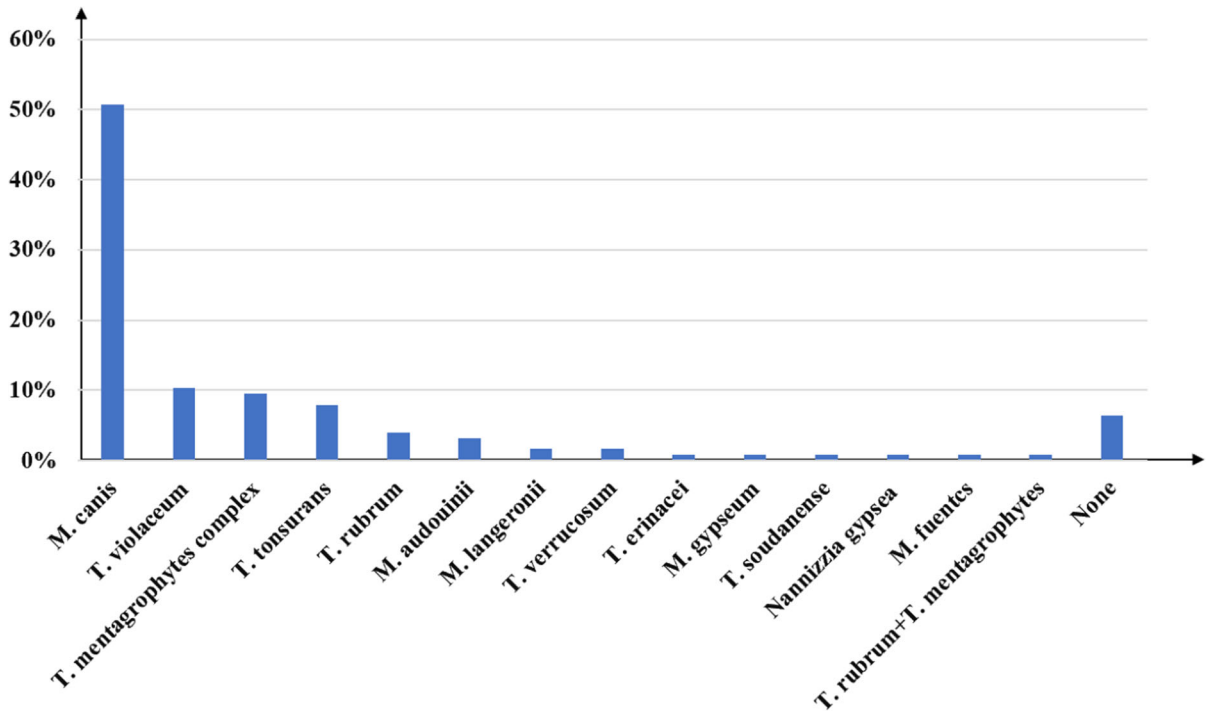


Fig. 3 The pathogenic organisms of tinea capitis in children under two years old

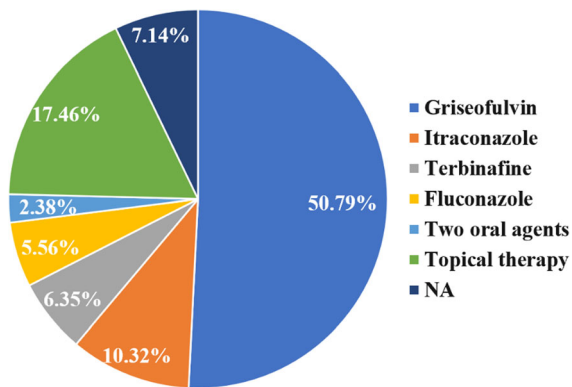


Fig. 4 Treatment strategies of tinea capitis in children in their first two years of life

consent of the guardian or severe clinical symptoms, treatment with systemic antifungal drugs should be recommended, and adverse reactions can be monitored; (ii) infants, especially neonates, with mild symptoms, underlying diseases or no agreement of their guardian, topical therapy should be considered; (iii) the combination of topical and systemic treatment for severe patients might increase the cure rate and shorten the duration of systemic antifungal drugs; (vi)

topical cream and antimycotic shampoo can be applied to reduce the transmission of infection and to decrease shedding of infected fungal elements [4].

In this study, we systematically summarized the epidemiological, clinical and pathogenic characteristics of TC in children less than two years old, and based on these data analysis, we gave the treatment recommendation. Oral treatment for pediatric TC were safe, and topical therapy can be an alternative choice, achieving good therapeutic effects. In sum, it is of great significance to improve the treatment for pediatric TC in younger children.

Author's Contribution GZL contributed to the study conception and design. Data collection and analysis were performed by GS, MJZ and XK. The first draft of the manuscript was written by GS and the revision of the article was done by GZL and WDL. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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