Dermatophytes are infections of skin, hair, and nails caused by species of the fungal genera *Trichophyton*, *Microsporum*, and *Epidermophyton*. These infections are of public health importance because of their transmissibility from human to human or from animal to human. Tinea capitis in particular remains a prevalent public health problem among school-aged children in the United States; a recent study demonstrated that 13% of elementary school children in Cleveland, Ohio, had positive scalp cultures for dermatophytic fungi (8). Sixty percent of these children were asymptomatic carriers (8). Others have shown that the incidence of tinea capitis is increasing. Lobato and colleagues found that the incidence rate in California for oral griseofulvin suspension prescriptions, a surrogate for tinea capitis, increased 84.2% from 1984 through 1993 (21). The increase in prescriptions among African-American children during this time period was 209.7% (21).

Despite the availability of newer antifungal drugs, treatment of tinea capitis remains a challenge. Systemic antifungal therapy is necessary to eradicate the disease, and currently only a single agent, griseofulvin, is approved by the U.S. Food and Drug Administration. Although griseofulvin therapy is usually well tolerated, the drug may cause gastrointestinal side effects and must be administered for a period of several weeks, making successful treatment of young children potentially difficult. Researchers have also reported concerns about the emergence of clinical tolerance to griseofulvin. In a recent trial, initial rates of response to griseofulvin therapy at the recommended dose of 11 mg/kg/day were only 52.2% at the end of 6 weeks of therapy and 57.0% at the end of 10 weeks of therapy (6). Fluconazole at 6 mg/kg/day administered for 6 weeks did not result in significantly better outcomes (6). Griseofulvin doses of up to 20 mg/kg/day for 8 weeks are currently utilized in clinical practice (3, 14).

The epidemiology of tinea capitis in the United States has changed dramatically over the past century, possibly due in part to the introduction of griseofulvin and the spread of dermatophyte species from South America to the United States. The predominant species causing tinea capitis in the United States during the first half of the 20th century was the anthropophilic species *Microsporum audouinii* (3). By the 1970s to 1980s *Trichophyton tonsurans*, another anthropophilic dermatophyte, had become the most common cause of tinea capitis (21), and it now causes more than 95% of these infections in the United States (7). By contrast, species such as *Trichophyton violaceum* and *Trichophyton soudanense*, which are common causes of tinea capitis in parts of Africa and West Asia (5, 15, 24, 25, 35), have rarely been isolated from patients in the United States. Among 14,696 dermatophytes isolated from patients at 54 locations throughout the United States from 1985 through 1987, only 12 were identified as *T. violaceum* and only 2 were identified as *T. soudanense* (31).

The present study was triggered by the identification of a cluster of *T. violaceum* and *T. soudanense* isolates recovered from multiple patients during the spring and early summer of 2005 in the Mycology Laboratory of The Johns Hopkins Hospital (JHH) in Baltimore, Maryland. The goals of this retrospective study were (i) to identify patients with positive cultures for these species from 2000 through June 2006, (ii) to present pertinent mycological findings, and (iii) to describe the epidemiology and characterize the clinical features of infections due to these organisms.

### MATERIALS AND METHODS

**Subject identification, data collection, and analysis.** Subjects were identified by searching JHH Mycology Laboratory records and the Department of Pathology Data Systems electronic database for cutaneous or hair cultures that were...
organism accounted for 1.5% of all dermatophytes. This difference was statistically significant ($P = 0.001$; Fisher’s exact test). By the first half of 2006, $T.$ violaceum and $T.$ soudanense accounted for almost 4% of all dermatophytes, and $T.$ soudanense was the second most common dermatophyte isolated from scalp and hair specimens (following $T.$ tonsurans).

Seventy-two percent (18/25) of $T.$ violaceum isolates were slow-growing, with waxy, glabrous, wrinkled colonies. Colonies were a distinctive, deep, purple-red and sometimes had a white, waxy fringe. Over time, some cultures became fluffy and lost their characteristic colony morphology. Colony morphology and microscopic characteristics of $T.$ violaceum (for example, lack of sporulation) may overlap with those of Trichophyton rubrum.

$T.$ soudanense isolates were also slow-growing. Colonies were flat, with a suede-like texture, a spidery edge, and a distinctive yellow or orange-yellow color. Over time, the colonies became folded and pleomorphic. Microscopically, no conidia were seen. Reflexive branching, in which the hypha bends back toward the inoculum site, was seen. This species may overlap with Microsporum ferrugineum. Colony color on mycobacterial Lowenstein-Jensen medium may allow for differentiation of the two species; $T.$ soudanense has brownish-black colonies, whereas $M.$ ferrugineum produces yellow colonies. Characteristic features of $T.$ violaceum and $T.$ soudanense are presented in standard mycology textbooks (19, 21, 27).
positive culture during the years 2000 to 2003, five patients in 2004, seven patients in 2005, and nine patients in the first 6 months of 2006.

Fourteen of 24 patients (58%) were male, and the median age at diagnosis was 5 years (range, 1 to 47 years). Information on country of origin was available for 16/24 patients (67%). Of these 16 patients, 14 (88%) were from countries in eastern Africa (including Kenya, Uganda, Somalia, Tanzania, and Ethiopia) and West Africa (Liberia and the Congo). Two patients were of U.S. origin. Of the 16 patients for whom duration of U.S. residence was reported, 11 (69%) had been in the United States for 2 years or less (5 for less than 3 months), and 5 (31%) had been in the United States for more than 2 years. Of 13 patients for whom duration of residence in Baltimore was available, 5 (38%) had lived in the city for <3 months, 4 (31%) for 6 to 12 months, 3 (23%) for 2 to 5 years, and 1 (8%) for more than 5 years.

Clinical information was available for 19 of 24 patients (79%) (Table 2). Of 14 patients diagnosed with tinea capitis, 11 (79%) were taking or had received griseofulvin for 6 to 8 weeks, 1 (7%) received topical therapy only, and 2 (14%) received no treatment. All 10 patients with tinea capitis for whom therapy was complete and follow-up was available were cured of their infections (including 2 patients who reportedly received no therapy). Of the remaining four patients, one had

Patients with dermatophytoses due to *T. violaceum* and *T. soudanense*. We identified 24 patients from whom 25 *T. violaceum* or *T. soudanense* isolates were recovered (Fig. 1). Twenty-three of 24 patients had single positive cultures. One patient had two positive cultures approximately 1.5 years apart. Nine of 24 patients had single positive cultures. One patient had a positive culture on October 15, 2017 by guest http://jcm.asm.org/ Downloaded from
not yet completed therapy and three were lost to follow-up. All subjects with tinea capitis were 12 years of age or younger. Four patients had tinea corporis (two children and two adults), and one adult patient had onychomycosis. Among the 19 patients for whom a clinical diagnosis was available, 3/15 patients infected with T. violaceum (20%) had a dermatophytosis other than tinea capitis (2 patients with tinea corporis involving the face and 1 patient with onychomycosis), and 2/4 patients infected with T. soudanense (50%) had tinea corporis involving the extremities and/or the trunk. Of note, the only patient noted to have relapsed in this series was a child with tinea capitis due to T. violaceum who initially received a low dose of griseofulvin and developed recurrent disease 1.5 years later. Although the source of the dermatophyte infection was unknown for most patients, two of the adult patients were reported to have children who had been diagnosed with tinea capitis or eczema.

DISCUSSION

We report a recent increase in the recovery of T. violaceum and T. soudanense from fungal cultures of skin, hair, and nail specimens processed in the JHH Mycology Laboratory. These organisms, which are common causes of dermatophytoses, particularly tinea capitis, in parts of Africa and Asia, have only sporadically been reported to cause disease in the United States. To our knowledge, ours is the largest U.S. series in several decades.

In contrast to the relatively high treatment failure rate reported in a U.S. study in which the predominant cause of tinea capitis was T. tonsurans (6), all children with tinea capitis in our series for whom follow-up information was available were cured of their infections after receiving 6 to 8 weeks of griseofulvin at doses ranging from approximately 10 to 20 mg/kg/day. Two patients reportedly had resolution of their infections without specific therapy. This observation of a high cure rate is in accordance with findings from a trial of once-weekly fluconazole for the treatment of tinea capitis in 61 children in Brazil, Canada, and South Africa (11). A complete cure 8 weeks after therapy was seen in 98% of children. Interestingly, almost half of these children had infection due to T. violaceum, while just 18% had infection due to T. tonsurans (11). Another trial of griseofulvin (20 mg/kg/day for 6 weeks), terbinafine, itraconazole (5 mg/kg/day for 2 to 3 weeks), and fluconazole (6 mg/kg/day for 2 to 3 weeks) for the treatment of tinea capitis in Canada and South Africa showed 100% response rates in each of the four treatment arms among subjects with disease due to T. violaceum, compared to rates of 80 to 92% for subjects with disease due to T. tonsurans (10). Although the numbers of subjects infected with T. violaceum were small, the data are suggestive. While the treatment regimens and duration of therapy were quite different in these trials and in our study, it is possible that T. violaceum is more susceptible to commonly used antifungal agents than T. tonsurans, accounting for the observed differences in response rates.

One plausible explanation for the observed increase in T. violaceum and T. soudanense isolation is a change in referral patterns from community clinics to the JHH clinical laboratory. However, JHH laboratory records indicated that the community clinic from whence some positive cultures were sent was sending its specimens to JHH during the entire duration of the study period (B. Filburn, personal communication). We believe that increased immigration to the Baltimore area from regions where T. violaceum and T. soudanense are endemic may be a more likely explanation for the observed increase in isolation of these species. Although publicly accessible immigration data specific to the Baltimore metropolitan area are limited, data from the U.S. Census Bureau indicate that the number of individuals born in Africa who entered the United States and established residence in Baltimore City has increased over the past few decades (33). For example, 534 African-born individuals entered the United States prior to 1980 and established residence in Baltimore City, compared to 828 African-born individuals entering the United States between 1980 and 1989 and 2,329 African-born individuals entering the United States between 1990 and March 2000 (33). Similarly, data from the Office of Immigration Statistics indicate that the percentage of African-born people becoming legal permanent residents and living in Maryland increased between 1980 and 2003 (34). In fact, 2003 data indicate that Maryland, the District of Columbia, California, and New York had the highest percentages of African-born people becoming legal permanent residents (34).

Investigators in other areas of the world where T. violaceum and T. soudanense are not endemic have also reported the emergence of these organisms in the setting of changing population demographics. Lamb and Rademaker reported 68 isolates of T. violaceum and T. soudanense obtained from 60 patients in Hamilton, New Zealand, most of whom were East African refugees who had settled in the region (18). Twenty isolates of T. violaceum causing tinea capitis and tinea corporis were identified over a 32-year period in a mycology laboratory in Melbourne, Australia. Affected patients were of Mediterranean, Australian Aboriginal, or Ethiopian origin (23). More recently, studies from Sweden, Finland, and Belgium have also reported isolation of T. violaceum and T. soudanense from children with tinea capitis, most of whom were African (particularly Somali) immigrants (12, 13, 17).

In the United States, reports of these organisms have been sporadic. In a 1949 series from Boston, Massachusetts, T. violaceum was reported to have caused a single case of tinea capitis among 78 cases of fungal scalp infection (4). Among subsequent reports in the 1950s and 1960s were three outbreaks of tinea capitis due to T. violaceum occurring in a state school in New York (30) and among family members in Detroit, Michigan (2) and in Texas (28). Another report from Detroit investigators in the late 1960s described two adult patients with tinea corporis caused by T. violaceum (32). Published reports of T. soudanense infections in the United States have been even more infrequent. Although more recent reports describing infections in the United States due to either T. violaceum or T. soudanense are rare, Ohio investigators in 2003 described two sisters adopted from Liberia who had tinea capitis caused by T. soudanense (22).

Because T. violaceum has been shown to be the most common cause of tinea capitis in a number of studies from West Asia and North Africa (1, 5, 16), while T. soudanense has been shown to be the most common cause of tinea capitis in a study of schoolchildren from the Ivory Coast (24), these organisms should be expected in children who have immigrated from...
these regions and have characteristic clinical findings. Since these species are rarely seen in the United States and usually fail to produce micro- or macroconidia, definitive identification may in some cases require molecular methods (20). Molecular taxonomy studies also suggest that T. soudanense (as well as other infrequently encountered species, such as T. gourvilli and T. yaoundei) is conspecific with T. violaceum, although their phenetics differ (9). A more recent study using a microsatellite marker has suggested that T. soudanense is actually more closely related to T. rubrum than to T. violaceum (26). These evolutionary relationships are interesting and require further study, probably necessitating sequencing of multiple regions.

Our findings provide evidence for the ongoing evolution of dermatophytosis epidemiology related to international travel and shifts in population demographics, although our study is limited by its small size, the lack of molecular confirmation of organism identities, and the amount of clinical and demographic information available for subjects. Physicians and laboratory scientists, in addition to public health officials, need to be made aware of such changes, and laboratory scientists, in addition to public health officials, need to be included in laboratory proficiency testing for proper diagnosis and treatment as well as disease geners to areas where they are not endemic will continue to occur and may in some circumstances have important implica-

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