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Epidemiologic Assessment of Scabies: Actuality of Airborne Transmission and Additional Standards to Reduce Spread of Contagion and Reinfestation

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Abstract:
Scabies are caused by parasites that live their entire life within the outer layers of the epidermis. When dislodged either by gravity, friction, motion, wind, or static electricity, they assume great risks to survival. Innate abilities to sense human smell and heat, to move over short distances, and to penetrate the skin quickly allow them a fighting chance to find a new host if they land within 4 inches of a human. Females store sperm, allowing one mite to begin a colony. Transmission is by person-to-person, fomite, and airborne. They are aerodynamic, light, and balloon-shaped, all making airborne transmission easier than previously understood, as well as explaining the dissemination of mites beyond the normal zones of activity of the index case.
Presently, the bulk of the medical literature suggests that transmission from inanimate objects poses little concern in common scabies. However, as mites can navigate through cloth gowns, one might consider protection with more protective garb. Mites cannot penetrate through waterproof clothing, and thus, this attire should be recommended to avoid reinfestation and infesting others. Sofas, chairs, office furniture, and car seats on which an index case might sit need to be covered with plastic sheeting. Given that the half-life of ivermectin is 18 hours and that mites dehydrate within 96 hours, strict transmission controls are only needed for 3 days to avoid reinfestation as well as infesting others.

Key Points: Scabies is an intensely itchy skin rash caused by a burrowing mite that infects the outer layers of the skin.
Scabies is contagious and usually spread by direct, prolonged skin-to-skin contact with an infected person; however, fomite and airborne transmission are also operative.
Precautions should be in place to avoid direct skin-to-skin contact between a patient with scabies and visitors. Waterproof clothing would be advisable, especially in cases involving Norwegian scabies.
Success rates with oral ivermectin would more closely approach 100% if all transmission factors, including fomite and airborne, were addressed.

Keywords: Scabies, Epidemiology, Airborne transmission, Fomite transmission, Airborne transmission, Parasitic disease, Reinfestation.

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1. INTRODUCTION

Human scabies is caused by the infestation with the host-specific mite *Sarcoptes scabiei* var. *hominis*, which lives its entire life within the outer layers of the epidermis

[1-6]. It causes severe pruritus, especially at night, which may or may not be associated with a symmetrical, pimple-like rash. Spread of the infestation among family members and other close contacts is common. The World Health Organization has formally designated this disease as a neglected tropical disease, underscoring scabies as a significant global health concern with an unacceptably high prevalence [7].

Scabies can present with papules and burrows in the finger webs, wrists, lateral aspects of the palms, genitalia, waist, axillae, and areola. Alternatively, there may be minimal cutaneous findings in consort with generalized intractable itch. Although no one is immune to infestation, the disease is most common in children, young adults, and elderly, bedridden patients. The incubation period before symptoms occur can range from days to months. A normal response would be two to six weeks before one's immune response is sensitized to the mite or its by-products. A subsequent infestation may require one to two days for pruritus to begin. Asymptomatic scabies-infested individuals are not uncommon, and they can be considered 'carriers' [8].

The diagnosis can be confirmed by conventional microscopy. A drop of immersion of mineral oil is placed on the scraping and then covered by a coverslip. The highest yield in finding the mite on scraping would be from a typical burrow on the finger webs, the flexural aspect of the wrist. The three diagnostic signs would be the mites, their eggs, and their fetal pellets (scybala).

The number of mites living on an infested host can vary greatly, although they are usually fewer than a hundred and often no more than 10 to 15 [9]. However, patients with crusted scabies (also called Norwegian scabies) may have thousands of mites on their skin surface and are highly contagious. Crusted scabies are found in individuals with compromised immune systems, such as due to age or, people with HIV or solid organ transplant recipients.

The inclusion of spatial dynamics reveals that scabies transmission occurs in traveling waves, indicating a more resilient host population [10]. Its decreased prevalence during COVID-19 suggests that physical distancing reduces its transmission.

1.1. Innate Survival Skills of the Mite

The female burrows into the interface of the stratum lucidum and stratum granulosum to lay its eggs, while the male roams closer to the surface in the horny layer of skin. Mites do not feed off the lysed stratum corneum but ingest intercellular fluid for nourishment [9]. Host IgG antibody in the guts of mites is evidence that mites ingest host serum [11]. The procurement of host intercellular fluid is necessary for mites to obtain sufficient water to maintain their water balance [12].

The mite has an oval tortoise-like body that is ventrally flat and dorsally convex. All terminal segments of the legs of both sexes of scabies have claws for mobility. They move 1 inch per hour on human skin. *Sarcoptes scabiei* var. *hominis* is 0.35 by 0.3 mm in size. They are light with a fresh weight of 5.6 +/-1.25 ug and a dry weight of 2.8 ug+/-0.86 ug. Males are smaller, and their wet weight is 1.49 +/- 0.59ug, and their dry weight is 0.39 +/- 0.16 ug. One female produces 40-50 eggs over a life span of 26-40 days. Like lice, female scabies mites, following copulation, store semen internally in the spermatheca, a pouch that serves as a storage organ for sperm. Thus, one female organism can start a new colony of mites in a new host.

Mites are blessed with certain features, which aid in their viability when introduced into a location free from their previous host. They can ascertain proximity to a potential host by sensors detecting heat as well as human odor. Studies revealed that 100% of female mites moved directly to the host when placed 4.2 cm (1.62 in) away [13]. About 20% of mites migrated to the host when placed 11.2 cm (4.4 in) away. Moreover, if mites find themselves within 4 inches of the host, they stand a good chance of survival.

Mites also have been attracted to the fluorescent overhead light [14], accentuating their tendency to live on the outer edges of the epidermis.

The time duration that mites can survive off a host is a major factor in assessing their viability when landing on an inanimate object. Of note, they live longer if the relative humidity is high and temperatures are colder. Mites are prone to dehydration as they have limited ability to maintain their water balance. Females survived a week at 59 degrees with relative humidity above 75%. At a warmer temperature of 77 degrees, mite survival was 1-2 days [15]. Human mites survived 19 days at 10 degrees Celsius and 97% humidity. However, in dry climates, mites endure for less than 36 hrs.

Mites have the ability to penetrate the host skin fairly quickly. Female mites have been timed to take 20 minutes to burrow into the skin to lay eggs [15]. They secrete a clear fluid (saliva) that dissolves the stratum corneum, allowing the mite to descend into a skin depression in the outer epidermal tissues. They use their legs to crawl and swim into place. Furthermore, they can contort their body to navigate small openings. To merely find a firm footing on a new host, a mite would take even less time. Given their small size, they can penetrate most clothing materials easily.

1.2. Three Methods of Scabies Transmission

Mites are transmitted by three distinct methods:

(1) The most common mode is person-to-person physical contact, sexual or otherwise, which is referred to as horizontal direct contact transmission. Spread of the infestation among family members and other close contacts is common.

(2) Indirect contact transmission is when mites leave their safe haven and land on objects, such as clothes, furniture, clothes, toys, towels, linens, and bedding. Fomite transmission is when a new susceptible host touches these inanimate objects and transfers the parasite to a susceptible portal of entry, the skin. Human mites are

positioned on the outermost skin layers, seemingly ready to take off their entire adult lives. They are programmed to leave their place for the hopeful colonization of a foreign host. If mites are rubbed off on sheeting or fall from their perch due to gravitational forces, that is referred to as normal fomite transmission.

(3) Vehicle transmission, in the case of scabies, refers to the transmission of pathogens through the air. Mites can be airborne due to kinetic, static electricity, or wind gusts. Kinetic energy is achieved from motion from the host, such as throwing a baseball, flicking rubber gloves off, or dancing. Of note, one of the body sites where mites reside is the hands and wrists [9], which are locations ideal for airborne transmission with the arm movement of the host. Another energy causing mites to go airborne would be static electricity. Static electricity in clothes is caused by the transfer of electrons between different fabrics when they rub together. It might occur with the removal of clothing and/or toweling. Additionally, gusts of wind, such as from a blow-dryer, fan, or forced air, could lead to airborne mites. If outside on a windy day, the distance of travel could potentially be further. Nature has made these organisms light and in the shape of balloons; they have minimal resistance anatomically, which might improve transport distance. For clarification, if a mite lands by gravity onto an inanimate object and then is resuspended into the air (for example, by a ventilating fan), this would then be defined as airborne transmission if it finds a new host or reinfests a previously treated individual.

The proof of airborne transmission would include that it is the first reasonable explanation for recovering mites on the floor, curtains, and chairs distant from the environment of affected individuals [16, 17]. An absence of knowledge for this form of transmission would also explain the lower-than-expected success rates with anti-scabietic treatments [18]. Differentiating airborne from fomite transmission has been pertinent in analyzing parameters for disease dissemination in other disease states [19]. Crusted scabies is presently felt to disperse mainly *via* fomite transmission, but airborne transmission, although never substantiated in the literature to date, would be operative in this condition as well [20, 21].

1.3. Present CDC Guidelines for the Control of Scabies Transmission

There is general agreement that for optimum preventive treatment, all family members and close contacts should be treated simultaneously with either oral or topical scabietic therapy. Simultaneously with treatment, individuals should wear clean clothing. All clothing, pillowcases, towels, and bedding used during the previous week should be washed in hot water and dried at high heat. Non-washables should be dry-cleaned, ironed, or stored in a sealed plastic bag in a warm area for 5 days. Floors, carpets, upholstery (in both homes and cars), play areas, and furniture should be carefully vacuumed. Fumigation of living spaces is not recommended.

The Centers for Disease Control also addresses the environmental control of mites in the institutional (hospital) setting. They have made three categories of scabies, namely, situations with a single case, multiple cases, and crusted scabies. For the first two forms, the CDC recommends avoiding direct contact as well as using gloves with hands-to-care for several days after the index case is treated. Only for the crusted variant, protective garments (gowns, disposable gloves, and shoe covers) are suggested.

As noted above, the CDC, as well as the bulk of the medical literature suggest that transmissions from inanimate objects may pose little concern in common scabies [1-6]. They suggest it is only important in a rare form of the disease called crusted scabies, in which the host has tens of thousands of mites, rather than less than a hundred in normal scabies. The CDC recommendations for crusted scabies include the use of gowns, disposable gloves, and shoe covers for three days after the treatment of scabies.

1.4. CDC Recommendations Might Need to be Expanded and Enhanced

Considering the transmission factors listed earlier, CDC recommendations for scabies need a few additions, including protecting index cases from reinfestation and infesting others. The enhancement relates to the fact that mites can navigate through cloth gowns, and one must protect against the mites with a more protective garb. Human mites are water-dependent and cannot navigate through waterproof materials [15]. Waterproof clothing should be recommended, which would include essential personal protective equipment (PPE) gowns that are made of polypropylene, as mites cannot penetrate such material. Other examples would include clothing often sold to painters and campers, rain gear for golfers, and parkas. Plastic bags, which are made of polyurethane, would be protective and could easily be worn over one's socks. Sofas, chairs, office furniture, and car seats need to be covered with plastic sheeting, which can be obtained at home improvement retailers. Blow dryers, fans, or major wind gusts in the house should be minimized, and if used, the air should be directed away from people.

1.5. The Use of Ivermectin

Ivermectin has been used in humans for oncho-cerciasis and strongyloidiasis since 1996. Although the FDA has not approved ivermectin for scabies, the CDC recommends it. With correct dosing, ivermectin kills the scabies mite on humans living in the skin layers entirely, as resistance is very rare. The only caveat is in patients with thickened nails and in patients with thick, crusted skin, topical agents would also be indicated for these areas. In such cases, a topical scabicide agent should be applied for 10 consecutive nights in addition to oral ivermectin.

Ivermectin reaches effective levels in the bloodstream within 4 hours and its half-life is 18 hours. The drug has an over a 2.5-fold increase in bioavailability when taken following a high-fat meal [22]. After one dose of ivermec-

stin, it can be assured that for one day, one will not have any viable mites on the body. If reinfestation does not occur, the condition is resolved. Mites that have left prior to the oral treatment have three days to find a host before dehydration and death. Thus, control and protection measures only last for 96 hours with attention directed to one's home, car, and workplace.

Clinical efficacy for scabies has been achieved with the identical dosing for strongyloidiasis, namely 200 ug/kg [23]. Akin to the CDC, it is suggested to treat scabies twice, one week apart [24]. The reason for the second treatment is to improve one's ability to avoid reinfestation, which is the cause of treatment failure with ivermectin. A lesser reason, that can now be ignored, is the concern as to whether the agent is 100% lethal to scabietic eggs, which might hatch days after the first treatment. In some countries like Italy, a single dose of ivermectin is recommended [25]. This means that a much more stringent adherence to fomite and airborne transmission is essential for cure.

Of note to this discussion, while taking oral ivermectin for three days, an index case of scabies would not have to worry about reinfestation from the environment. Transmission control would not be eliminated entirely as there would still be a risk of infesting another individual who is in close proximity during those three days. In severe cases, such as crusted scabies, and recalcitrant cases, a treatment of three days of oral ivermectin might be considered.

CONCLUSION

More clinical studies adhering to more rigid standardized control of fomite and airborne transmission of these parasites are needed. Eliminating reinfestation in patients will better reflect the true rates of success with the oral and topical medications available. Presently, reinfestation due to poor attention to fomite and airborne transmission skews the results.

Scabies has been known for millennia [26]. It is caused by parasites with natural traits and adaptive capabilities that have surpassed human abilities to eliminate them from existence so far.

AUTHORS' CONTRIBUTION

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

ABBREVIATION

PPE = Personal Protective Equipment

CONSENT FOR PUBLICATION

Not applicable.

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CONFLICT OF INTEREST

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