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Scabies

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Received: Sept 20, 2022 Accepted: Dec 30, 2022

INTRODUCTION

Sarcoptic scabies (animal scabies, pseudo-scabies, canine scabies) is a contagious skin disease that affects both humans and wild and domestic animals. It is caused by the mite *Sarcoptes* (S.) *scabiei* (Bandi and Saikumar 2013; Chandler and Fuller 2019; Rowe et al. 2019; Turchetto et al. 2020; Moroni et al. 2022). It is transmitted to humans through contact with other infected humans or animals (Bandi and Saikumar 2013; Moroni et al. 2022). Scabies affects more than 150 mammalian species worldwide (Moroni et al. 2022). It is regarded as a permanent parasite, with a short life cycle. Diagnosis is confirmed by observing its presence in multiple superficial skin scrapings (Moroni et al. 2022).

The history of scabies was described by Dr. Reuben Friedman in the first half of the 20th century. In the Old Testament, "*zaraath"* is the term used for scabies. Aristotle and Galen noted the contagious nature of scabies, and the former used the term 'mite'. Celsus described sheep scabies and its treatment. Avenzoar described mites as small flesh worms that crawl under the skin and cause water-filled pustules. In the 13th-16th centuries, the presence of mites was observed in scabies lesions, but the causal link was not established. In the 17th century, Hauptman sketched imperfect mites. Giovanni Cosimo and Diacinto Cestoni studied the disease in sailors and produced a drawing of the mite in 1687 (Currier et al. 2011). In 1746, Linnaeus classified the mite as *Acarus humanus-subcutaneous*. The first accurate illustration of the parasite was sketched by DeGeer. Simon Françoís Renucci obtained a mite specimen from a young girl suffering from "the itch" on August 13, 1834. In the late 19th and early 20th centuries, Ferdinand Ritter von Hebra described the life cycle and stages of infection. Kenneth Mellanby described measures for scabies environmental disinfection during World War II (Currier et al. 2011). Scabies was listed by the World Health Organization as a neglected tropical disease in 2017 (Moroni et al. 2022).

Etiology

Scabies is caused by *Sarcoptes* (*S.*) *scabiei*. The name of the parasite comes from the Greek word *sarx*, meaning 'flesh', and *koptein*, meaning 'to cut', plus the Latin word *scabere*, meaning 'to scratch' (Hicks and Elston 2009). It is an arthropod of the class Arachnida, subclass Acari, order Astigmata, suborder Acaridida (Astigmata)—because it has no detectable spiracles or tracheal system— and family Sarcoptidae. Several, host-specific varieties have been described in the genus *Sarcoptes* (*S. scabiei* var. *canis*, *S. scabiei* var. *bovis*, *S. scabiei* var. *suis*, *S. scabiei* var. *equi*, *S. scabiei* var. *aucheniae*, *S. scabiei* var. *cuniculi*, *S. scabiei* var. *ovis* and *S. scabiei* var. *caprae*, which parasitize dogs, cattle, pigs, horses, llamas and alpacas, rabbits or goats, respectively). The subspecies infecting humans is *S. scabiei* var. *hominis*, which is distinct from that affecting animals (Burgess 1994; Chosidow 2006; Hicks and Elston 2009; Aydıngöz and Mansur 2011; Agusti et al. 2012; Gallegos et al. 2014).

The female mite is 300–500 µm long, 230–420 µm wide, and the male is 213–285 µm long, 162–210 µm wide (Burgess 1994). *S. scabiei* has a thin cuticle without heavily sclerotized scutes, a head with brown sclerotized mouthparts, and no division between abdomen and cephalothorax (Hicks and Elston 2009; Gallegos et al. 2014). It is pearly white or creamy white in color, translucent, small, oval, and flattened in shape, with eight legs attached to the ventral surface of the cephalothorax. The first two pairs of horny legs bear two claws (Chouela et al. 2002).

Epidemiology

Scabies is a globally distributed disease; however, it is most common in developing countries. It affects various domestic and wild species, as well as humans, as *Sarcoptes* variants have evolved to infest specific host species. Transmission occurs primarily through direct contact, which is favored by crowding or when animals are kept together in confined areas (Foreyt 2001).

Citation: Adán GB, Juan MMJ, Nelly MVA, Paulino SS, Benedicta BLM and Guadalupe NM, 2023. Scabies. In: Aguilar-Marcelino L, Younus M, Khan A, Saeed NM and Abbas RZ (eds), One Health Triad, Unique Scientific Publishers, Faisalabad, Pakistan, Vol. 3, pp: 245-250. https://doi.org/10.47278/book.oht/2023.102

The exact number of infected cases are still unknown, however, over 300 million people are estimated to be affected. It is considered endemic mainly in tropical regions, with a variable prevalence, which in certain regions can be 5–10% (Hay et al. 2012). In a study conducted in Brazil in 2005, a frequency of 8.8% was determined in poor neighborhoods, versus 3.8% in a fishing community. However, this study found no variation in frequency in different seasons of the year (Heukelbach et al. 2005) in contrast to the findings of Mimouni et al. (2003), who reported a higher frequency in winter, probably favored by overcrowding during colder months.

Historically, younger age groups have been more vulnerable, and the frequency decreases in adults, while increasing again in the elder people. This distribution is consistent with the findings of Lapeere et al. (2008) in Belgium, where the incidence was higher in the elderly. In a study conducted in Cuba in children aged 0–14 years diagnosed with scabies, 69% were younger than 1 year. No difference was found with respect to gender. Interestingly, 45% of cases were in the poor socioeconomic segment (Saldaña 2020), in agreement with the findings reported in Brazil by Feldmeier et al. (2008) in which in addition to poverty, a low educational level was mentioned as a risk factor, possibly due to poverty conditions as a base element.

In the United Kingdom, Lassa et al. (2011) conducted a study and found a higher frequency in females than in males, with a relative risk of 1.24, along with a higher frequency in people aged 10–19 years. The authors identified an epidemic cycle of 15–17 years.

Pathogenesis

Scabies occurs mainly in immunocompromised patients, whether due to HIV infection, steroid treatment (systemic or topical), transplant surgery, or hematological malignancies (Remartínez et al. 2009). It is also prevalent in patients with physical or mental disability, including paralysis, sensory neuropathy, leprosy, or Down syndrome (DS). Subjects with an inability to perceive pruritus or those who are incapable of scratching are also susceptible (Singh et al. 2011; Roldán-Franco et al. 2019).

The biological cycle of the mite starts when female and male mate on the skin surface. A single copulation is sufficient for a lifetime of egg-laying. After mating, the male dies and the female digs shallow passages called burrows, where she lays eggs (Gallegos et al. 2014). The gravid female reaches the stratum corneum using her jaws and cutting claws. As she advances, she sucks tissue fluids to feed, leaving feces behind as she continues to burrow (Hicks and Elston 2009). Saliva and feces provoke a hypersensitivity reaction, causing widespread inflammatory responses in the skin (Currie and McCarthy 2010).

The female lays 2–3 eggs per day, which hatch after approximately 55 hours to produce nymphs that resemble the adult mite but are smaller and only have three leg pairs. The nymphs leave the burrow one day later and move to the skin surface. The adult female dies after 5 weeks. During this time, she will spread the burrow at a speed of 0.5–5 mm per day. She can survive for 24–36 hours at room temperature (Chouela et al. 2002; Hicks and Elston 2009).

The mite population can increase to 25 adult females after 50 days, and up to 500 mites by 100 days, producing the cutaneous eruption characteristic of classical scabies. This is caused by both infestation and hypersensitivity reaction (Chosidow 2006; Hicks and Elston 2009) and is observed as intensely pruritic erythematous furrows, vesicles, crusts, and papules resulting from a type IV delayed hypersensitivity reaction. Scabies can also occur as a psoriasiform dermatosis, affecting hands and feet (Gallegos et al. 2014; Harris and Vincek 2017). Lesions are most common on hand interdigital membranes and periungual areas, flexor surfaces of the wrists, the scalp, face and back (Currie and McCarthy 2010; Palaniappan et al. 2021).

Transmission

Scabies is transmitted primarily by close contact with infected individuals and, less frequently, by sharing clothing, sheets, or towels (Aussy et al. 2019). Although few mite subspecies can infect humans, there is a great variety of subspecies that can infect animals (de Gentile and Carsuzaa 2013). In animal-human transmission, companion animals are the main transmitting agents, followed by production animals such as rabbits, cattle (bovines and buffaloes), llamas, and pigs, and to a lesser extent, wild species such as gazelles and monkeys, due to the unusual contact between these species and humans (Moroni et al. 2022).

Clinical Variants

Three clinical variants of scabies are recognized. According to the symptoms, it can be classic/simple, crusted/profuse, or nodular (Plascencia et al. 2013).

Classic scabies. The main signs are pruritus and the occurrence of furrows and vesicles. Intense pruritus is an effect of mite burrowing, and in generalized cases it is related to an allergic reaction, with a typical increase in immunoglobulin E (IgE) levels. Furrows and vesicles are often found in the interdigital spaces of the hands and in the folds of the anterior aspect of the wrist, while the axillary folds, mammary papillae, umbilicus, genital organs, back, scalp, and face are less frequently affected; however, the entire body may be involved (de Gentile and Carsuzaa 2013). Pruritus begins 4–6 weeks after infection. In cases of reinfestation within 6 months after initial infection, it will develop within hours or days. In very severe cases, disseminated erythematous papules, excoriations, hemorrhagic crusts, linear scrapes (dermatitis), vesicles, and often pustules are found due to secondary bacterial infection.

Bruising problem which is secondary to rubbing and scratching is also common. The severity of signs varies from person to person (Richards 2020).

Crusted scabies. It occurs in immunocompromised patients. Its main trait is the absence of pruritus, which makes it difficult to diagnose. Lesions and desquamation products carry abundant parasites, which increases its infectivity (Barrutia 2021). It presents with marked hyperkeratosis involving the limbs, including subungual areas, although lesions may be generalized. Peripheral eosinophilia is usually the main sign in patients with keratinization disorders (Galiana et al. 2003). Compared to classical scabies, crusted scabies presents with localized keratotic plaques on the limbs, trunk, pinnae, and eyelids (Tirado-Sánchez et al. 2016).

Nodular scabies. It presents with erythematous nodules up to 2-cm in diameter. It is the least common variant (7%), and it mainly involves the buttocks, genitals, groin, or armpits. These lesions may be the result of a hypersensitivity reaction to the mite's secretion products (Plascencia et al. 2013).

Diagnosis

Definitive diagnosis requires microscopic detection of the mite, its feces, or eggs. However, in classical scabies the number of mites is scarce, so this method is limited, and a negative examination does not rule out the diagnosis. Therefore, physical examination and a compatible history allow establishing a diagnosis of suspicion and initiating treatment (Barrutia 2021). There are several diagnostic methods, including the following:

Müller's test: It consists of a cutaneous scraping, applying 1–2 drops of mineral oil or petroleum jelly on the lesion, which is scraped with a scalpel blade to extract the upper part of the tunnels. The sample is placed and spread on a slide, covered with a coverslip, and observed under a microscope (Morgado-Carrasco et al. 2021).

Burrow ink test: It consists of the direct application of blue-black ink on suspicious lesions, cleaning the surface with alcohol afterwards. The ink penetrates in the epidermal tunnels excavated by mites, facilitating the visualization of the furrow and, thus, differential diagnosis is possible with other pruritic dermatoses (Silvestre et al. 2020).

Dermatoscopy or epiluminescence microscopy: With this technique, the parasite can be observed in situ at 10X magnification. The sensitivity of this technique is 91%, and its specificity is 86% (de Gentile and Carsuzaa 2021). Small triangular structures can be observed, which correspond to the pigmented anterior section of the mite, and a linear segment behind the triangle, which contains small air bubbles, corresponds to the tunnels, eggs, and feces of the parasite (Morales and Matute 2008).

***In vivo* reflectance confocal microscopy (RCM):** Its usefulness has been reported to diagnose scabies and other parasites (Morgado-Carrasco et al. 2021). This technique allows a rapid and non-invasive confirmatory diagnosis. In scabies, it allows real-time observation of mites, eggs, and scybala. This technique also allows to monitor the response to treatment, as indicators of active infection can be observed, such as the presence of eggs in the furrows (Fusta et al. 2019).

Polymerase chain reaction (PCR): A PCR assay has been used recently to demonstrate scabies in patients presenting with clinically atypical eczema. In these cases, epidermal scales are usually PCR-positive for *S. scabiei* DNA before treatment and negative two weeks after treatment (Morales and Matute 2008).

Treatment

Various alternatives are available to treat scabies. The choice will depend on the clinical presentation and the patient's resources. In addition to medication, hygienic measures are required for a successful treatment, such as thorough cleaning of bedding and contaminated clothing, as well as the disposal of fomites that have had contact with companion animals or production animals, if these were the transmitters of the parasite (FitzGerald et al. 2014).

Cleaning measures are accompanied by the application of specific chemical agents against scabies; the best known are benzyl benzoate, lindane (1%), esdepallethrine/piperonyl butoxide, pyrethroids, macrocyclic lactones (de Gentile and Carsuzaa 2021), crotamiton, methotrexate, and sulfur (Plascencia et al. 2013). Other compounds have also been reported as active against the parasite, such as beuvericin, which at a concentration of 0.5% was effective in eliminating both adult parasites and eggs (AlKhoury et al. 2020).

Alternative treatments with plant extracts to eliminate the parasite have also been reported (Nakamura et al. 2022). A recent study lists about 28 plants, including fruit trees such as papaya (*Carica papaya*), where the whole plant can be used for treatment with effective results (Akram et al. 2020). The efficacy of some plants in eliminating the parasite can be due to their content of active compounds like alkaloids, tannins, flavonoids, and coumarin derivatives (Altaf et al. 2018).

Prevention

The disease can be prevented in humans by considering some risk factors, particularly avoiding overcrowding, which can be especially difficult in vulnerable groups because it involves changing the economic conditions in a household. In places such as hospitals, nursing homes for the elderly or schools, where outbreaks occur with some frequency, early detection and effective treatment are important (Jadraque et al. 2010). Likewise, health promotion activities should be carried out in endemic sites to enable the population and animal owners to recognize the routes of transmission of the disease and identify the problem at an early stage (Peraza 2021).

Those individuals who having close contact with animals or people infected with scabies should wear gloves, especially

when a person or animal is suspected of being infected (Jadraque et al. 2010).

Zoonosis

Scabies is a zoonotic disease that affects humans and a wide range of domestic and wild animals (Aydıngöz and Mansur 2011). It has been reported that the mite is not species-specific, but can temporarily live on other species, giving rise to cross-infection (Aydıngöz and Mansur 2011; Gallegos et al. 2014). Moroni et al. (2022) conducted a literature review on the zoonotic transmission of this parasite, focusing on outbreak sources, transmission, and diagnosis of strains involved in human cases, as well as on the treatments applied. Among the nine species of companion animals identified, dogs, cats, and goats accounted for the highest number of transmission cases, while miniature pigs, horses, rabbits, water buffaloes, llamas, and cattle were identified in a smaller proportion as transmission sources for their owners. Other domestic animals, and wild species (foxes, wombats, gazelles, chamois, and monkeys) may also serve as an occupational source for spread of disease to human.

Epidemiology: Parasitic diseases are very frequent, particularly, scabies due to *S. scabiei* var. *canis* shows a high zoonotic potential, accounting for 2–4% of all dermatological cases. It is noteworthy that there is not much information on prevalence indicators in animal populations, probably because when a case is identified, it is treated on a casuistic basis, with no records on its incidence or prevalence (Gakuya et al. 2012).

Pigs

Several works have reported the presence of scabies in pigs. The transmission from adults to young pigs is important, especially during lactation. Cordero et al. (2001) and Pedroso-de-Paiva et al. (2003) found that the key risk factors associated with the presence of disease are that pigs inhabit an area of less than 0.85 m^2/pig and have an air volume of less than 3.0 m^3/animal.

Dogs

Some authors report that it affects dogs of any breed, sex, or age, and can sometimes occur sub-clinically (Corrales et al. 2001), although others point out that it mainly affects young and short-haired animals (Quintero 2006).

Wild Species

Bornstein et al. (2001) reported the presence of scabies in six primate species, 11 canids, nine felids, six mustelids, two procyonids, and a wide variety of artiodactyls, as well as in rodents, lagomorphs, marsupials, and insectivores. Therefore, it is likely to affect more species than reported in the literature. Gakuya et al. (2012) reported this parasitic disease in African lions, gazelles, wildebeests, and cheetahs, with infection frequencies up to 12.7% in the latter species, and marginal frequencies of less than 1% in the others. It is noteworthy that the highest frequency was found in areas of coexistence with domestic species in the Masai Mara region, in Kenya.

Rasero et al. (2010) conducted a study in three European countries, using ten specific markers for *Sarcoptes* and determining the genotype through microsatellites. Variations in genotype were observed according to geographical segregation, with three major groups according to the host: herbivorous, carnivorous, and omnivorous. Segregation has generated new mite subpopulations, indicating host-specific adaptation of the parasites, as Walton et al. (2004) previously described in Australia.

Sheep and Goats

In sheep and goats, the *Sarcoptes* mite causes skin thickening, scabs, and alopecia around the mouth, in addition to erythematous papules around the eyes, ears, and legs, resulting in great economic losses for owners (Lastuti et al. 2018). Unshorn sheep are more affected, as humidity and dirt favor the perpetuation of the parasite life cycle. In Indonesia, prevalence rates of 5–100% were reported in goat herds, and mortality could be high in young animals, increasing the production costs for these animals (Lastuti et al. 2018).

Transmission: It occurs by direct contact, but cases of transmission by contaminated objects have been reported, as these parasites can survive for some time outside the body of the animals. Clothing, cleaning utensils, bedding, harnesses, and blankets can be sources of contamination. In pigs and other animals, viable parasites have been found on the walls and bars of pens. Although each animal species is a reservoir of the mite for its conspecifics, cross-transmission between different species has also occurred (Aussy et al. 2019).

Recent studies in Japan have found other routes of animal-to-animal transmission, such as hunter-prey interaction. This is not limited to wild species, but it can also be observed in the interaction of feral dogs and cats with their prey (Matsuyama et al. 2019).

Signs: Similar lesions occur in all animal species affected by this parasitosis. They begin or end at the point where the mite first enters the skin. Initially, small red papules and erythema of the skin may be observed, showing the entry site of the mite, as well as a local serous exudation that transforms into a superficial wet coagulum, with intense pruritus. Continued irritation gives rise to a subacute dermatitis with active parakeratotic proliferation and the formation of thin crusts, which eventually thicken and desiccate due to the large numbers of bacteria growing on them (Jubb et al. 2007); thus, secondary bacterial infections are frequent (Gakuya et al. 2012). Hairs are lost in these areas, and the skin thickens and shows discoloration (Quintero 2006).

Two clinical presentations can be found in pigs: the first one resembles an allergy, and it is common in young animals and piglets and after 2–10-week incubation, numerous red spots are observed all over the body of the animals. The second one, which manifests as hyperkeratosis, is usual in adult and old animals; the main sign is pruritus; additionally, the skin of the tail, snout, legs, and the inner side of ears in these animals shows abundant scabs (Fernández et al. 2018).

Treatment: Various topical scabicide products are available in the market. Sulfur formulations are less used nowadays as these may cause dermatitis. Benzyl benzoate, lindane, and crotamiton are commonly used. Topical acaricides available include permethrin 5%, deltamethrin 0.02%, lindane 1%, sulfur petrolatum 6–10%, crotamiton 10%, and in refractory cases oral ivermectin is recommended at a dose of 200 µg/kg once, repeated after two weeks (Osman et al. 2006).

Prevention: In animals, primary prevention requires adequate environmental sanitation, including washing and disinfection of areas where affected animals are kept, as well as avoiding overcrowding (Valdés 1997; Pedroso-de-Pavia et al. 2003). In dogs, it is common to apply secondary prevention, through early diagnosis and timely treatment. In that sense, it is advantageous that the disease is visible and can be diagnosed in early stages. For slaughter animals, it is important to separate the affected animal(s) to avoid transmission to the rest of the animals, and to apply the appropriate treatment. An integrated health approach is required to prevent the infection and, if necessary, control scabies outbreaks in places where cases have been observed, and where coexistence between humans, domestic, and wild animals is common (Rubini 2021).

Conclusion

Scabies is a neglected parasitic disease that is a major public health problem in many resource-poor regions. It causes substantial morbidity from secondary infections and post-infective complications. It is a disease of zoonotic importance, which affects different species and man, causing great economic losses. So, it is important to maintain a prevention and control system, especially in those species that are in close contact with each other and with humans.

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