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Insect Vectors Involving in Mechanical Transmission of Human Pathogens for Serious Diseases

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Abstract

Despite efforts of modern medicine, spread of arthropod-borne diseases is still one of the most serious concerns facing by public health officials and medical community in general. Health medical entomologists work in the public health arena, dealing with insects and other arthropods that parasitize, bite, sting and are vectors that transmit diseases to humans. Some important insects that parasitize humans are lice, fleas, bedbugs, ticks and scabies mites, while biting insects include mosquitoes, midges, sand flies, black flies, horse flies and stable flies, all of which may be vectors of pathogens. This article discusses mechanical transmission of pathogenic microbes by insect vectors, explores the different ways humans get infected and discusses the control measures against vectors. Majority of disease-causing organisms are arthropods (85%), among which insects and arachnids are of great medical importance. Insects spread diseases primarily via stings, bites, infestation of tissues and indirect transmission of pathogens. Vectors such as house fly, eye gnats, ants and cockroaches spread diseases by literally carrying pathogens on the surface of their bodies from place to place. Medically most important vectors are the common house fly (*Musca domestica*) and the greater house fly (*Muscina stabulans*), both having a more or less worldwide distribution. House flies can be vectors of helminths, faecal bacteria, protozoans and viruses, leading to the spread of enteric diseases (dysenteries and typhoids). Cockroaches specifically *Blattella germanica* and *Periplaneta americana* carry disease-causing organisms, typically those causing gastroenteritis. They carry disease-causing organisms on the legs and bodies and deposit on food as they forage. Excrement and cast skins of roaches also contain a number of allergens. Losses caused by arthropod-borne diseases include not only the direct costs of medicine and health care, but also indirect costs resulting from stress, absenteeism and reduced productivity. Maintenance of good hygiene, vector control and vaccination are very important to prevent the spread of these infectious diseases. Vector borne diseases, most of which are transmitted in and around the homes, are best controlled by a combination of vector control practices, medicines and vaccines. The process of bringing vector control into the mainstream strategy for future eradication emphasizes that new strategies for prevention and control of vector-borne diseases should be conducted through integrated vector management plan.

Keywords

Pathogen, Microbe, Mechanical Vector, Arthropod-Borne Disease

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1. Introduction

Tropical diseases are primarily diseases of poverty. They are responsible for major economic burdens through disability, death of principal earners, and missed educational opportunities for children and young adults, thus entrapping in poverty quagmire. It is no coincidence that the countries most affected by these diseases are amongst the poorest countries in the world. Vector-borne diseases are infectious diseases or illnesses transmitted through insects such as mosquitoes, sand

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flies, ticks, fleas, lice, bugs and flies. Vectors are classified as biological vectors such as mosquitoes and bedbugs which carry pathogens within their bodies and transmit by biting or mechanical vectors which includes flies that carry infectious agents on the surface of their bodies and transmit them via physical contact with the host. Human acquisition of vector-borne diseases passes through three stages, the presence of the pathologic agent, attachment of pathogen to the arthropod vector and transmission to the human host. Although epidemics of arthropod-borne disease have been well-documented throughout human history, yet it became known later on that insects and related arthropods are linked to the spread of human diseases. Infectious agents that cause illness or disease in other living organisms are known as pathogens. These agents include a wide variety of microorganisms (mycoplasmas, bacteria, protozoa, spirochetes and rickettsiae) as well as fungi, helminths (roundworms and flatworms) and viruses. A host is any living organism that is infected by a pathogen, regardless of symptoms of the disease. The host may succumb to disease or may overcome the infection, or may retain the pathogen in a condition of readiness to infect other hosts. Whenever the host serves as a source of new infection for other hosts (of the same or different species), it is known as a reservoir. Pathogens are generally carried from one host to another by vectors. The word biocenosis may be utilized for signifying a biological set which comprises pathogen and totally of its vectors and hosts. Some pathogens may have multiple hosts, reservoirs, or vectors such as *Pasteurella tularensis*, the tularemia pathogen, that can be transmitted to humans by deer flies, ticks, fleas, or body lice from reservoirs in rodents as well as other humans. Other pathogens, like the *Plasmodium s*pecies that cause malaria, have a much narrower biocenosis, as they can survive only within their human hosts and mosquito vector. Finally, cholera and amoebic dysentery causing pathogens can survive for long periods outside the bodies of living hosts. These communicable mediators are frequently transmitted to humans through flies or else by other insects which come in contact with filth and rubbish (Mullen and Durden, 2002; Eldridge and Edman, 2004; Sarwar et al., 2015).

2. Mechanical Transmission of Pathogens

Under certain circumstances, pathogens can merely stick to a vector's legs or mouthparts and are transmittable to a fresh host, this is recognized as mechanical transmission. Maximum of the pathogens which are transferred mechanically are capable to persist for an instant exposure to the environment and sunlight. Different kinds of arboviruses (short for arthropod-borne viruses) are transmittable through mechanical transmission on the mouthparts of mosquitoes. In contrast, biological transmission occurs when the pathogen survives for a period of time inside the vector's body and is later spread to another host. Some of these pathogens relocate within the body of the vector traveling from the gut to the salivary glands. Others, such as the rickettsia of Rocky Mountain spotted fever, remain dormant in the tick vector's+ body and only become activated after feeding commences. Therefore, removing a tick within 1-2 h of attachment usually will ensure too little time for activation and transmission of its pathogens (Sarwar et al., 2014; 2015a; 2015b).

Mechanical transmission occurs when the parasite is transmitted among vertebrate hosts without amplification or development within the vector, usually by contaminated mouthparts. Arthropods that are associated intimately with their vertebrate hosts and feed at frequent intervals have a greater probability of transmitting parasites mechanically. The role of the arthropod is essentially an extension of contact transmission between vertebrate hosts. For instance, eye gnats bear rasping- sponging mouthparts and forage repetitively on the mucous membranes of a diversity of vertebrate hosts, creating to these a real mechanical vector of the bacteria that are basis for ‘pink eye’ or conjunctivitis. Mechanical transmission may also be accomplished by contaminated mouthparts if the vector is interrupted while blood feeding and then immediately refeeds on a second host in an attempt to complete the blood meal (Foil and Gorham, 2004).

With mechanical transmission, there is no development or multiplication of a disease agent within a vector. There are two types of mechanical transmission by arthropods: - 1) The disease agents are transferred directly between two hosts (direct mechanical transmission). Non-biting insects that are attracted to open sores or lacrimal secretions of infected vertebrates are involved in direct transmission. 2) Arthropods transmit pathogens picked up from substrates contaminated by secretory and or excretory products of infected hosts (indirect, or contaminative, mechanical transmission). Ants and roaches are examples of arthropods implicated in indirect transmission. House flies and related Diptera may be involved in both types of transmission. Mechanically transmitted pathogens may multiply not only within the original source host, but also in various environmental media such as water, soil, or manure (Gorham, 1994; Olson, 1998). For instance, most likely plants do not provide optimal conditions for growth of human enteric pathogens, but pathogens use different mechanisms to tightly attach to favorable sites on plant organs and to fit harsh conditions in order to survive in the plants long enough and in sufficient numbers for successful infection of new mammalian hosts with consequence of a significant number of outbreaks (Yaron and Romling, 2014).

If inadequate local and worldwide competences for distinguishing, recognizing and speaking are given to vector-borne diseases, the significant monetary, environmental and public health impacts are probable to continue for their epidemics. Much remains to be discovered about the biology of these diseases, and in particular, about the complex biological and ecological relationships that exist among pathogens, vectors, hosts and their environments. Such type of information is vital for the enhancement of innovative and further active mediation and modification procedures for control of vector-borne diseases (Mughal et al., 2015).

3. Mechanical Transmission by Vectors

The following sections discuss arthropods involved in mechanical transmission of pathogens and the control measures that can be applied to prevent systematic spread of vectors.

3.1. House Flies (Muscidae: Diptera)

The housefly is a very common and cosmopolitan species which transmits diseases to humans. House flies often live among filth and garbage, and can carry the pathogens for dysentery (*Shigella dysenteriae*), typhoid fever (*Eberthella typhosa*) and cholera (*Vibrio comma*) on their feet and mouthparts. In addition, house flies may also spread rickettsiae of Q fever (*Coxiella burnetii*); viruses of polio, coxsackie and infectious hepatitis; bacteria such as cholera (*Vibrio cholerae*), anthrax, *Campylobacter*, *Shigella, Salmonella*, *Escherichia coli*, *Staphylococcus aureus*; spirochaetes of yaws (*Treponema pertenue*); and protozoans including *Entamoeba*, *Cryptosporidium* and *Giardia*. In addition, house flies can carry eggs of a variety of helminths, for example *Taenia*, *Ancylostoma*, *Dipylidium*, *Diphyllobothrium*, *Enterobius*, *Trichuris* and *Ascaris*. Eye-worms (*Thelazia* species) are rather rare infections of the eye and are transmitted biologically by *Musca* species. Pathogenic fungi such as *Microsporum canis* causing 'tinea capitis' in humans have also been found in fly's excreta. Many of the pathogens transmitted by the house fly are probably also spread by another fly species, the greater house flies (*Muscina stabulans*). Both fly species have also been suspected as a vector of the viral agent causing poliomyelitis. The organisms of both amoebic and bacillary dysenteries are picked up by flies from the feces of infected people and transferred to clean food either from the fly's hairs or by the fly's vomiting during feeding. Typhoid germs may also be deposited on food with the fly's feces. The house fly causes the spread of yaws germs by carrying them from a yaws ulcer to an ordinary sore (Service, 2012; Sarwar et al., 2014).

Cholera and hepatitis are sometimes fly-borne from filthiness, but houseflies transmit poliomyelitis by carrying the virus from infected feces to food or drinks. Other diseases carried by houseflies are salmonellosis, tuberculosis, anthrax and some forms of ophthalmia. They carry over 100 pathogens and transmit eggs of some parasitic worms like roundworms. The flies in lower-hygiene areas usually carry more pathogens. Some strains have become immune to most common insecticides. Houseflies are one of the most important public health pests which live in close association with peoples all over the world and feed on all kinds of human food, garbage, and excreta, including animal dung. Water is an essential component of a fly's diet and flies cannot normally live more than 48 h without access to it. Other common sources of food are milk, sugar, blood, meat broth and many other materials found in human settlements. Flies evidently need to feed at least two to three times a day. Female flies deposit their eggs on decayed, fermenting, or rotting organic material of either animal or vegetable origin. Heaps of accumulated animal feces, garbage, sewage sludge, and solid organic waste in open drains, cesspools, and cesspits are most important breeding sites for houseflies. During daytime when not actively feeding, flies may be found resting on floor, walls, ceiling, and other interior surfaces as well as outdoor on the ground, fences, walls, steps, simple pit latrines, garbage cans, etc. These resting places are generally near favoured daytime feeding and breeding areas, and they are sheltered from the wind. Those that stick to outer surfaces of fly may survive for few hours, but those that are ingested with the food may survive in fly's crop or gut for several days. Transmission takes place when the fly makes contact with people or food. Few other diseases that flies can transmit include enteric infections such as dysentery, certain helminths infections, eye infections like trachoma, and certain skin infection such as cutaneous diphtheria, some mycoses and leprosy (Graczyk et al., 2001; Rahuma et al., 2005).

Larvae of the house flies have occasionally been recorded causing urogenital and traumatic myiasis, and more rarely aural and nasopharyngeal myiasis. If food infected with fly maggots is eaten, then they may be passed more or less intact in the excreta, often causing considerable alarm and surprise. House flies can transmit a large number of infections to humans because of their habits of visiting, almost indiscriminately, feces and other unhygienic matter and people's food. Pathogens can be transmitted by three possible routes: - 1) By flies' contaminated feet, body hairs and mouthparts. Most pathogens, however, remain viable on the fly for less than 24 h and are usually insufficient to cause direct infection, except possibly with *Shigella*. However, pathogens multiply sufficiently if first transferred to food to reach the level of an infective dose. 2) By flies vomiting on food during feeding, which they do frequently. 3) By defecation, which often occurs on food; this is probably the most important method of transmission (Chavasse et al., 1999). Control methods against house flies can be divided conveniently into three categories, physical and mechanical control, environmental sanitation, and insecticidal control (Sarwar et al., 2015a; 2015b; 2015c).

3.1.1. Physical and Mechanical Control

Flies can sometimes be prevented from entering buildings by covering doors and openings with plastic screening having a mesh size of 3-4 strands per centimetre (2-3 openings per centimetre). Screening can be costly, but they may be worthwhile in hospitals and restaurants. Although screening can reduce fly nuisance, flies can continue to breed locally and enter unscreened houses. Air currents, such as the air barriers found in the entrances of some shops and fans mounted over doorways may reduce the number of flies entering premises. Placing curtains of vertical, often colored strips of plastic or beading in doorways also helps to keep the flies out. Restaurants, food stores and hospitals often mount ultraviolet light-traps on walls to attract flies, which are then killed by an electric grid. Commercially available sticky tapes (fly-papers), incorporating sugar as an attractant, can be relatively effective, although unsightly in catching flies.

3.1.2. Environmental Sanitation

This aims at reducing house fly populations by minimizing their larval habitats, that is by source reduction. For example, domestic refuse and garbage should be placed either in strong plastic bags with the openings tightly closed, or in dustbins with tight-fitting lids. Regular refuse collections in warm countries helps to prevent eggs laid on the garbage. The household refuse which cannot be disposed should be burnt or buried. Unhygienic rubbish dumps, often found in towns and villages, provide ideal breeding sites, and should be eliminated.

3.1.3. Insecticidal Control

Larvicidal insecticides can be directed against the larvae by spraying the insides of dustbins as well as the refuse and garbage heaps, manure piles, and other breeding sites. Insect growth regulators such as diflubenzuron, cyromazine, or pyriproxyfen are also useful. Usually large volumes (0.5-5 L / m^2) are needed to penetrate the upper 10-15 cm of breeding sites to reach the larvae. Spraying against adults by commercial aerosol spray cans or small hand sprayers can be used indoors to kill adult flies. Suitable insecticides include organophosphates such as malathion, pyrethroids and permethrin. Care should be taken to avoid contaminating the food with insecticides. Aerosol applications and space-spraying have virtually no residual effects, consequently treatments have to be repeated, and this can be costly.

3.2. Eye Gnats (Chloropidae: Diptera)

Adults are small (1.5 to 5 mm in length), with few large bristles and a prominent break in the costal vein of the wing just mesial of the subcostal junction. Many adults are commonly found in grasses and other low vegetation or visiting flowers. Some known species of eye gnats including *Liohippelates* and *Siphunculina* species are attracted to humans and other mammals, where they hover about the face, body orifices, and open wounds. The adults hover around the head of humans, causing annoyance, especially when they fly into eyes, nostrils, or mouths. The *Liohippelates* species have been implicated in the mechanical transmission of several pathogens of humans and livestock. The *Treponema pertenue*, the spirochete that causes yaws, has been shown to be transmitted by *L. flavipes* in some locations. Human's acute conjunctivitis (pink eye), caused by several bacterial species is noticeably more prevalent during outbreaks of *Liohippelates* and *Siphunculina*. The *Liohippelates* species have also been implicated in the spread of the causative organisms of *Vesicular stomatitis* in livestock and streptococcal infections of humans. There are no effective area-wide methods for controlling *Liohippelates* species. Temporary relief from their annoyance is provided by protective head nets and insect repellents containing N, N-diethyl-m-toluamide (DEET) in humans (Cranston, 1988; Hall and Gerhardt, 2002).

3.3. Ants (Formicidae: Hymenoptera)

Ants are ubiquitous, occurring throughout most of the world including most oceanic islands. In tropical regions ant species have also been implicated as vectors of pathogens. The only ants of significant medical-veterinary importance are the fire ants (*Solenopsis* and *Wasmannia* spp.), and harvester ants (*Pogonomyrmex* spp.). The bulk of literature on the role of ants as mechanical vectors is much smaller than that for either flies or cockroaches. It has been noted and confirmed that *Vibrio cholerae* could be recovered from ants and cockroaches. Hughes et al., (1989) captured ants in a veterinary clinic laboratory, and using blood agar plates, isolated species of *Serratia*, *Citrobacter*, *Klebsiella*, *Enterobacter*, *Proteus*, *Staphylococcus* and *Yersinia* including *Yersinia pestis*, which can cause outbreaks of foodborne illness that are harmful to humans medically. There are two main types of ant problems that are commonly encountered, ants that live outside and forage inside homes, and ants that already have a nest built inside a home. The ants can be eliminated or prevented from entering by filling and sealing cracks and crevices to eliminate passages into the home, cleaning around entry points with a detergent to remove the chemical trail of pheromone along their established routes to and from a food source, and spraying non-repellent residual insecticide to help prevent either type of infestation.

3.4. Cockroaches (Blattidae: Dictyoptera)

Cockroaches are sometimes called roaches or steam bugs and these have an almost worldwide distribution. The most important medically are *Blattella germanica* (German cockroach), *Blatta orientalis* (Oriental cockroach), *Periplaneta americana* (American cockroach), *P. australasiae* (Australian cockroach), and *Supella longipalpa* (brown-banded cockroach). Cockroaches aid in the mechanical transmission of various pathogenic viruses, bacteria and protozoans. Cockroaches are common pest in homes, restaurants, hospitals, warehouses, offices and in storage areas. Cockroaches are nocturnal and remain hiding in dark and warm areas especially in narrow spaces. They are rapid breeders, and just a couple of roaches can produce large number of offspring in just a few weeks particularly during and after extended rain period. Cockroaches tend to congregate in corners and generally travel along the edges of walls or other surfaces. Cockroaches contaminate food and eating utensils, destroy fabric and paper products, and impart stains and unpleasant odors to surfaces they contact. Some cockroaches (American cockroach) can transmit bacteria that cause food poisoning (*Salmonella* spp., and *Shigella* spp.). German cockroaches transmit disease-causing organisms such as *Staphylococcus* spp., *Streptococcus* spp., hepatitis virus and coliform bacteria (Rust and Reierson, 2007). They have been implicated in the spread of typhoid and diarrhea, dysentery, leprosy and plague. Indoor infestations of roaches are an important source of allergens and risk for asthma among some populations. The organisms causing these diseases are carried on the legs and bodies of cockroaches, and deposited on food and utensils as roaches feed and move about (Mukhtar, 2010).

3.4.1. Allergies Due to Cockroaches

Only recently, the relative importance of cockroach allergies has been recognized. About half of asthmatics are allergic to cockroaches, their cast-off skins or excreta, while about 10% of non-asthmatic persons can exhibit cockroach allergies. Symptoms include sneezing, skin reactions, sore eyes, recurrent ear infections and in extreme cases shortness of breath (Stelmach et al., 2002; Gore and Schal, 2007).

3.4.2. Infectious Agents

Because of their habits of feeding indiscriminately on both excreta and foods, and excreting and regurgitating partially digested meals over food, the presence of cockroaches in houses, hotels and hospitals is not surprisingly, highly undesirable. Most parasitic infections isolated from cockroaches are also spread directly from person to person without the aid of intermediary insects; therefore, it is usually difficult to prove that cockroaches are responsible for any disease outbreak. Nevertheless, because of their unsanitary habits they have been suspected as aiding in the transmission of various pathogens. More than 40 pathogenic and nonpathogenic bacterial species have been isolated from cockroaches, including *Entamoeba histolytica, Escherichia coli, Klebsiella pneumoniae, Mycobacterium leprae, Shigella dysenteriae*, and *Salmonella* species, including *S. typhi* and *S. typhimurium*, *Serratia* species, and *Staphylococcus aureus*. Eggs of the nematode *Enterobius vermicularis*, which is an extremely common worm in humans, can also be carried by cockroaches. There is little doubt that cockroaches contribute to the spread of several infections, mainly intestinal ones. Roaches may possibly be more important as mechanical vectors than house flies. However, it is difficult to assess their real importance as vectors because many of the pathogens which cockroaches carry can be transmitted in various other ways. The cockroaches are also implicated in the spread of at least some pathogens like hepatitis (Pai et al., 2008; Mpuchane et al., 2006; Karimi and Vatani, 2009).

3.4.3. Prevention of Cockroach Infestation

Cockroaches are difficult to control with insecticides, and the use of chemical alone provides temporary relief. For effective and long lasting control of roaches, application of chemicals should be combined with environmental sanitation and home improvement practices that include the reduction of food and water source as well as removal of potential breeding spots, thus limiting the cockroach's ability to establish or reinvade. Integrated Vector Management approach (IVM) for cockroaches control is effective if it includes physical and mechanical control, environmental sanitation, and insecticidal control.

3.4.4. Chemical Control

Ensuring that neither food nor dirty kitchen utensils are left overnight will help reduce the number of cockroaches, however their presence in nearby homes, will not deter the roaches from entering clean homes. Sites such as cupboards, wardrobes, kitchen furniture, underneath sinks, stoves, refrigerators and dustbins can be sprayed with insecticides. Good control can be achieved when dinotefuran, imidacloprid (nicotinoids), or sulfluramid (sulfonamide) insecticides are added to baits, such as peanut butter, dog food and maltose, to which glycerol may be added to increase their attractiveness. Such poisonous baits are best placed in areas having large numbers of cockroaches. Alternatively cockroach pheromones can be placed in simple cardboard or sticky traps to entice cockroaches into them, after which they are either killed or prevented from escaping. However, baits by themselves will not eliminate all cockroaches (Petersen and Shurdut, 1999).

Insect vectors are cold-blooded (ectothermic) and thus sensitive to climatic factors. Environmental factors, especially temperature and humidity, also affect how successful different pathogens can become. Weather influences survival and reproduction rates of vectors, and in turn influencing habitat suitability, distribution, abundance; intensity, and temporal pattern of vector activity (particularly biting rates) throughout the year, and rates of development, survival and reproduction of pathogens within vectors. However, climate is only one of many factors influencing vector's distribution, such as habitat destruction, land use, pesticide application and host density (Rogers and Randolph, 2006; Confalonieri et al., 2007).

4. Conclusion

This article covers some of diseases spread by mechanical vectors. Historically, successful vector-borne disease prevention resulted from management or elimination of vector populations. Air, water, food, and insects, all of these elements are critical to the survival of vector species and when in excess can also lead to sickness and cause disease. This article, therefore, explores some of the many ways by which a person can be infected directly or indirectly and spread of the illness to others through vectors. It is impossible to measure the full impact of insects and other arthropods on human health and welfare. These organisms have the capacity to inflict injury, disease, discomfort, or distress. They can be a direct cause of illness, pain, and suffering through bites and stings, infested wounds, or allergic reactions. They feed on blood or body tissues and transmit deadly pathogens or parasites. Economic losses associated with these vectors are borne not only by the affected individuals and their families, but also by human society in general. These costs are not easy to measure in dollars and cents, and practical advice on how to identify insects and other arthropods of medical importance, the health conditions they cause, and current recommendations for management and treatment are of crucial significance.

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