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A REVIEW

Strategies for prevention, control and eradication of zoonotic diseases

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Abstract : Zoonotic diseases have a significant effect on public health worldwide, showing a higher incidence rate in developing countries due to lack of control strategies, as well as the lack of education in the communities. About 75 per cent of emerging infectious disease in humans originates from animals. There are many factors that favor the spread of zoonotic diseases include change in farming practices; social, cultural, religious and lifestyle habits; rapid population growth; increasing poverty and urban migration; more frequent movement across international boundaries by tourists, workers, immigrants, and refugees; alterations in the habitats of animals and arthropod vectors that transmit disease; increasing numbers of persons with impaired host defenses; and changes in the way that food is processed and distributed. Therefore, collaboration between medical and veterinary scientists as well as public health practitioners and laboratory scientists is essential in order to investigate new and emerging zoonotic diseases. Fully equipped laboratories that contain subtyping technique tools are also essential to detect disease outbreaks and characterizing transmission routes. By using molecular subtyping, different strains can be differentiated based on their genotypes and phenotypes. In addition to laboratory techniques, the work of epidemiologists, ecologists, and environmentalists is crucial in establishing patterns and preventing outbreaks of zoonotic diseases.

Key words : Zoonoses, Prevention, Control, Eradication, Elimination

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INTRODUCTION

The expert committee of WHO (1959) has defined zoonoses as “those diseases and infections which are naturally transmitted between vertebrate animals and man”. Of the 1415 microbial diseases affecting humans, 61 per cent are zoonotic with 13 per cent species regarded as emerging or re-emerging (Taylor *et al.,* 2001). Among emerging infectious diseases, 75 per cent are zoonotic with wildlife being one of the major sources of infection (Daszak *et al.,* 2001). Zoonotic diseases are responsible for a large burden on the public health, livestock economies and wildlife of India (Knobel *et al.,* 2005). Zoonoses occur throughout the world transcending the natural boundaries (Ichhpujani *et*

al., 2000). There are many reasons for the increased occurrence of zoonotic diseases, including alteration of the environment, establishment of human settlements in formerly uninhabited areas, a greater demand for animal proteins, intensification of animal production and acceleration of trade in live animals, animal products and other foodstuffs (WHO, 2002). Animals play an important role in the transmission of zoonotic diseases. In general, the pathogenic species responsible for zoonotic diseases can survive and multiply without the presence of man (Burnet and White, 1972). In most cases (e.g., rabies, brucellosis, trichinellosis), man is a dead-end host and therefore not even useful for the perpetuation of the pathogenic agent. Zoonoses may be caused by bacteria, viruses, fungi and parasites. The closer contact with companion animals and rapid socio-economic changes in food production system has increased the number of animal-borne bacterial zoonoses (Cantas and Suer, 2014).

Emerging and re-emerging zoonoses:

Some zoonotic diseases have expanded their range of host and increased in incidence; these types of zoonosis are called emerging zoonoses (e.g., Ebola, Severe Acute Respiratory Syndrome, Swine flu, Bird flu, and Hantavirus) (Taylor *et al*., 2001). According to a report, approximately 75 per cent of recently emerging infectious diseases of humans is diseases of animal origin, therefore, indicating that the burden of zoonotic disease is an ongoing health concern (Merianos, 2007). In the last two decades, zoonotic diseases within the United States have increased in prevalence and have become a significant cause of infectious disease to humans; hence the need for continuous awareness (Sanyaolu *et al*., 2016). A new variant of a fatal neurologic illness, Creutzfeldt-Jakob disease, appeared in the United Kingdom and was possibly transmitted by ingestion of beef from animals afflicted with bovine spongiform encephalopathy, also known as "mad cow disease." This disease might be caused by a newly recognized type of transmissible agent called a prion (Prusiner, 1996). A new and virulent strain of influenza in Hong Kong raised fears of a global pandemic (CDC, 1997). A new strain of tuberculosis (strain W), which is multidrug-resistant and appears more frequently in persons with HIV infection, has become endemic in New York (Frieden *et al*., 1996).

Factors influencing emergence and re-emergence of zoonotic diseases:

Several factors are responsible for emergence or re-emergence of zoonotic diseases. The rate of zoonotic disease incidence and prevalence has been on the rise since the 1940s, most likely due to increased travelling, urbanization, demographic changes, encroachment of land, agricultural practices and human lifestyle (Mitura and Pietro, 2004). Zoonotic diseases have an impact on socio-economic status, for instance, an outbreak of bovine encephalopathy costs an estimate of $6.3 billion annually; foodborne zoonotic disease costs about $1.3 billion annually (Mitura and Pietro, 2004).

Breakdown of the host's defences can be associated with an immunodepression, either following medication or infection caused by pathogenic agents capable of weakening the host's immune defences allowing infection by opportunistic organisms. The best known example is that of the acquired Immunodeficiency syndrome (AIDS) during which certain bacteria, for which humans are usually healthy carriers, multiply to a level such that they lead to the death of their host (Weiss, 2003). Interestingly, human's adventurous nature has increased the burden of zoonotic diseases. Venturing into the wild increases the chance of coming in contact with infected animals or insects (Morse, 2004). Furthermore, the expansion of human population has led to land expansion and modern development in animal's natural habitat (McMichael, 2004). This urbanization further increases the risk of being exposed to infected animals.

Ecological changes due to agricultural and economic development are among the most frequently identified factors in the emergence of zoonoses. Accelerated degradation of the natural environment, notably in developed countries by deforestation, building of dams, land consolidation may cause wildlife species to move to new areas, favouring their relocation in sub-urban zones, therefore, entering into contact with humans (Chomel, 1980). The outbreak of Hantavirus pulmonary syndrome in the south western United States in 1993 is an example. It is likely that the virus has long been present in mouse populations but an unusually mild and wet winter and spring in that area led to an increased rodent population in the spring and summer and thus to greater opportunities for people to come in contact with infected rodents (and, hence, with the virus); it has been suggested that the weather anomaly was due to large-scale climatic effects (Levins*et al*., 1993). The emergence of Lyme disease in the United States and Europe

was probably due largely to reforestation (Barbour and Fish, 1993) which increased the population of deer and the deer tick, the vector of Lyme disease. The movement of people into these areas placed a larger population in close proximity to the vector.

Change in farming practices is one of the most common ways in which people alter and interpose themselves into the environment, is often a factor. Hantaan virus, the cause of Korean hemorrhagic fever, causes over 100,000 cases a year in China and has been known in Asia for centuries. The virus is a natural infection of the field mouse *Apodemus agrarius*. The rodent flourishes in rice fields; people usually contract the disease during the rice harvest from contact with infected rodents. Junin virus, the cause of Argentine hemorrhagic fever, is an unrelated virus with a history remarkably similar to that of Hantaan virus. Conversion of grassland to maize cultivation favoured a rodent that was the natural host for this virus and human cases increased in proportion with expansion of maize agriculture (Johnson, 1993). Irrigation is one of the agricultural practices used extensively for increased production and frequently associated with disease emergence. This may be associated with the emergence of mosquito-borne diseases and snail infestation. Infections transmitted by mosquitoes or other arthropods (WHO, 1989) are often stimulated by expansion of standing water. Outbreaks of Rift Valley fever in some parts of Africa have been associated with dam building as well as with periods of heavy rainfall (Monath, 1993).

Changes in human demographics and behaviour also cause emergence of zoonotic diseases. High prevalence of dengue hemorrhagic fever is attributed to the proliferation of mosquitoes in open containers needed for water storage (Monath, 1993). In industrialized countries like the United States, infections such as tuberculosis can spread through high-population density settings like day care centres or prisons (Bloom and Murray, 1992). In Africa, the close contact between human and livestock populations have led to major health problems, and in particular to the creation of a cycle of degradation and disease affecting especially traditional pastoral systems with a close physical association between people, livestock, and wild animals (Kock *et al.,* 2002).

Microbial adaptation is one of the most important factors associated with the emergence of zoonoses. Micro-organisms, like all other living things, are constantly evolving. The emergence of antibiotic-resistant bacteria as a result of the ubiquity of antimicrobials in the environment is an evolutionary lesson on microbial adaptation, as well as a demonstration of the power of natural selection. Selection for antibiotic-resistant bacteria (Davies, 1940) and drug-resistant parasites has become frequent, driven by the wide and sometimes inappropriate use of antimicrobial drugs in a variety of applications (Neu, 1992). Pathogens can also acquire new antibiotic resistance genes from other, often non-pathogenic, species in the environment (Davies, 1940) selected or perhaps even driven by the selection pressure of antibiotics. Antigenic drift in influenza virus, genetic changes in severe acute respiratory syndrome (SARS) corona virus in humans, development of antimicrobial resistance in HIV, multi-drug resistant TB and chloroquene resistant malaria are few examples of microbial changes. Many viruses show a high mutation rate and can rapidly evolve to yield new variants (Domingo and Holland, 1994).

Technological changes and industrialization are important cause of emergence and re-emergence of zoonotic diseases. The development of industries in the food production system for animals and humans followed by its worldwide distribution can be also increase the risk of contamination (Arora and Arora, 2008). The industrialization provides the opportunity to introduce agents from far away. A pathogen present in some of the raw material may find its way into a large batch of final product, as happened with the contamination of hamburger meat by *E. coli* strains causing hemolytic uremic syndrome. Bovine spongiform encephalopathy (BSE), which emerged in Britain, was likely an interspecies transfer of scrapie from sheep to cattle that occurred when changes in rendering processes led to incomplete inactivation of scrapie agent in sheep by-products fed to cattle (Wilesmith *et al.*, 1991). Social and cultural factors such as food habits and religious beliefs also play important role in the emergence of zoonoses (WHO, 2016). Breakdown of public health measures also cause emergence of zoonotic diseases. Deficiencies in public health infrastructure have been important cause of emergence of zoonotic diseases. The rapid spread of cholera in South America may have been abetted by reductions in chlorine levels used to treat water supplies (Moore, 1992).

International travel and trade are important causes of emergence of zoonotic diseases. Increasing international trade in live animals and foodstuff has favoured the spread of food-borne zoonotic diseases especially salmonellosis, campylobacteriosis etc. The spread of HIV has been increased due to international travel. In the past, an infection

introduced into people in a geographically isolated area might, on occasion, be brought to a new place through travel, commerce, or war (McNeill, 1976).*Aedes albopictus* (the Asian tiger mosquito) was introduced into the United States, Brazil, and parts of Africa in shipments of used tires from Asia. Since its introduction in 1982, this mosquito has established itself in at least 18 states of the United States and has acquired local viruses including Eastern equine encephalomyelitis (CDC, 1991). International trade has also caused emergence of enteric bacterial pathogens such as *Escherichia coli* O157:H7, *Salmonella* Enteritidis and *Listeria monocytogenes* (WHO, 2003). *Vibrio cholerae* O139 or an epidemic strain of *Neisseria meningitidis* (Moore, 1992) have disseminated rapidly along routes of trade and travel, as have antibiotic-resistant bacteria (Soares *et al.*, 1993 and Davies, 1940).

Prevention of zoonotic diseases :

Prevention implies all measures taken to exclude a disease from an unaffected (healthy) population. Prevention is the first line of defense against disease. Prevention of a disease in a population can be done by adopting following measures.

Quarantine:

It is a restraint placed upon the movement of man, animals, plants or goods which are suspected being of carriers or vehicle of infection or of having been exposed to infection. In general sense quarantine refers to detention of animals suspected of disease at port or land borders. Quarantine is the oldest of tools of preventive medicine. The aim of quarantine is to prevent the healthy native animals from coming in contact with imported infected animals or biomaterials. The first international livestock quarantine imposed by the United States was put into effect in 1890. Quarantine period was originally fixed as 40 days but now days it is left to the discretion of the appropriate authorities, who in most the cases are veterinary officer. As per model rules the period of quarantine can be extended to 90 days. As for as man is concerned, international sanitary regulations are directed against six so-called quarantinable diseases as yellow fever, small pox, cholera, plague, louse-borne typhus and louse-borne relapsing fever.

Mass immunization:

The second preventive tool is the mass immunization of population. Depending on the epidemiological situation, the pattern of animal movements, the occurrence of wildlife reservoirs, population density and production systems within the country, targeted vaccination may be more effective than systematic mass vaccination (OIE, 2014).

Environmental measures:

Third group of preventive technique is measures for environmental control. In addition to measures to ensure safe water supplies, environmental measures include air sanitation, food protection and control, pest and vector control, improvement of housing, in the case of man, sanitation of swimming pools, bathing beaches etc., excrement treatment and disposal and garbage disposal.

Health education:

This is the most effective preventive device. It includes see the posters, notices, handbills so crowded with small type. Education to be most effective as a preventive tool, must work towards engendering an assumption of initiative disease prevention.

Chemoprophylaxis:

It includes all uses of chemicals in the prevention of illness. Progress has been realized in preventing rheumatic fever through prophylactic administration of penicillin on a regular schedule to persons who have had streptococcal infection. It is also useful as repellents against both ectoparasites and insect vectors.

Early detection:

This method is especially suited to chronic infectious diseases and diseases of non infectious nature. The use of

tuberculin test first in domestic animal populations then in human populations is a classic example of early detection of tuberculosis. There are some other tests which can be used for the early detection of particular disease, e.g., brucellin test, mallein test, histoplasmin test, sporotrichin test, Casoni test and Widal test for brucellosis, glanders, histoplasmosis, sporotrichosis, hydatid disease and *Salmonella* infection, respectively.

Control of zoonotic diseases :

Disease control is a broad term generally used to describe all measures taken to combat illness among members of a population and to eliminate cause of illness which may exist in the environment. Lack of authentic data and awareness regarding the occurrence of these diseases and their true impact on public health have acted as major obstacles in commencing adequate and effective control measures (Asokan *et al.,* 2011). To combat emerging zoonoses it is better to know the epidemiology, route of entrance and the factors leading to such diseases (Alemayehu, 2012). During the implementation of a control programme, constant surveillance is imperative for monitoring and evaluation purposes and to supply reports on any unforeseen occurrence of diseases or significant changes in epidemiological patterns. Another essential element in successful surveillance is detailed knowledge of the territory, which should include local factors such as the characteristics of human and animal populations, existing habitats, climatic and geographical features (Mantovani, 1991). There are several methods by which the disease can be controlled.

Test and slaughter:

In this method the affected animals are detected through mass surveys and removed from the population by subjected them to premature slaughter. Stray dog elimination has been an effective measure against rabies and hydatid disease. Test and slaughter is not initially practical where the prevalence of infection is very high or in instances where the availability of replacement stock presents a real problem. The principle disadvantages of this approach are its high initial cost in operation and little compensation and the fact that it is often difficult approach to "sell" to farmers.

Mass treatment:

Mass treatment of the affected population may be carried out either in emergency situation or when disease prevalence is very high and the drug used is very safe. Early uses of this tactic were routine addition of coccidiostats to poultry drinking water, routine incorporation of anthelmintics into ruminant salt licks or feeds, use of some nutritional supplement mixes and some therapeutic incorporation of antibiotics in feeds. In the case mass antibiotic use, development and spread of drug resistant micro-organism is possible.

Vector control:

The general principles of vector control are as follows:

Environmental control:

It includes elimination of breeding places of pests, filling and drainage operation, careful planned water management, provision of piped water supply, proper disposal of refuse and other wastes and cleaning in and around house. Many actions which are relevant for zoonoses control are also important for protection of the environment (WHO, 1991). Intensive health educations of the public as well as political supports are essential prerequisites. Vegetation clearance has proven as effective control against chrysops, loa loa and tse tse fly vectors of the trypanosomes. Vegetation clearance along with water courses has been locally effective in both anopheline mosquito and snail control.

Chemical control:

A wide range of insecticides belonging to the organophosphorus (abate, chlorpyrefos, dichlorvos, malathion, parathion), organochlorines (aldrin, dialdrin, BHC, DDT, lindane, methoxychlor) and carbamates (cabaryl, dimetilan, pyrolan, propoxur) group of compounds are available of vector control. To avoid undue environmental pollution, it is

now considered essential to replace gradually the highly persistent compounds which are readily "biodegradable" and less toxic to man and animals, such as dursban, abate and methoxychlor. Insecticide application has been a particularly difficult matter in instance where vectors breed swiftly flowing water, as do simulidae or in densely vegetated areas as does chrysops in West Africa. Demerits of use of insecticides for vector control includes not fully effective due to development of resistance in many arthropod vectors and it causes environmental pollution.

Biological control:

It means control of vectors, reservoir host or a parasite by the introduction of natural enemies into a habitat. To minimize the environmental pollution with toxic chemicals, great emphasis is now placed on biological control. *Bacillus sphaericus, Bacillus thuringiensis* var *israelensis, Bacillus sphaericus* and pathogenic microsporidian such as *Thelokomia opecita* have been used for control of mosquitoes. Larvivorous fish like *Gambusia affinis, Lebister reticulates* (*Barbados millions*), Barbel fish and Giant gourami fish are important natural enemies against vectors like mosquitoes and cyclops. Growing of the water fern *Azolla microphylla* in rice field has been found as a biological agent against mosquitoes breeding in rice fields. Moreover, some bacteria and parasites have been successful against snail vectors which resulted into reduced schistosomiasis. A variety of biological agents like bacteria, viruses, fungi, nematodes and protozoa are under study for control of insects. But the fear exists that the introduction of biological agents for the control of arthropods may pose a direct hazard to the health of man himself.

Genetic control:

The WHO/ICMR research unit at New Delhi has contributed massively to the techniques of genetic control of mosquitoes. The techniques such as sterile male techniques, cytoplasmic incompatibility and chromosomal translocation have been found to be effective in very small field trials.

Newer methods:

New and innovative methods such as chemosterilants and sexattractants or pheromones are being sought for pest control.

Integrated approach:

Since no single method of control is likely to provide a solution in all situations, the present trend is to adopt an " Integrated approach" for vector control combining two or more methods with a view to obtain maximum results with the minimum effort and to avoid the excessive use of any one method.

Reservoir control:

This approach has met with great success in measures directed against rats, stray dogs and other noxious reservoir hosts of infection such as leptospirosis, plague, typhus and rabies. Stray dog elimination has been an effective measure against hydatid disease and rabies. Trapping or poisoning of foxes as well as other wild host is also helpful in controlling rabies. Anti-rodent measures are applicable only when a population of expendable wild animals acts as reservoir for an infection of domestic animals or of man. Rodents can be controlled by adopting following measures-

Sanitation measure:

It includes proper storage, collection and disposal of garbage; proper storage of food stuffs; construction of rat proof buildings, godowns and warehouses; and elimination of rat burrows by blocking them with concrete.

Trapping:

The traps are usually baited with indigenous foods of the locality. The captured rats must be destroyed which may be done by drowning them in water.

Fumigation:

It is effective against both rat and rat fleas. The fumigants which can be used are calcium cyanide (often called cynogas or cymag), carbon disulphide, methyl bromide, sulpher dioxide etc. Cynogas has been extensively used in India for the fumigation of rat burrows.

Chemosterilization:

Chemosterilants cause temporary or permanent sterility in either sex or both sexes. Rodent chemosterilants are still in the experimental stage.

Rodenticides:

Rodenticides are of two main types. Single dose (acute) rodenticides are lethal to the rat after single feeding. Multiple doses (cumulative) rodenticides which require repeated feeding over a period of 3 or more days. These include warfarin, pindone, diphacinone and coumafuryl. The commonly used rodenticide in India are zinc phosphide and barium carbonate.

Miscellaneous measures:

There are a number of other specialized approaches by which the disease can be controlled by using heat, cold irradiation and other physical and chemical sterilization procedures.

Eradication of zoonotic diseases:

The third strategy of population medicine is that of disease eradication. The literal meaning of eradication is "Tear out by roots". It means complete removal of a disease from an area or country. Eradication implies action and completeness; it is not eradication if a single individual of the parasite species remains. Today, small pox is the only disease that has been eradicated during recent years; three diseases have been seriously advanced as candidates for global eradication within the foreseeable future. Such diseases are polio, measles and dracunculiasis. There are two successful technical approaches to the regional eradication of infections, one is the test and slaughter and other is the vector control. Mass immunization has also been used in the regional eradication of a few infections such as small pox in humans.

Test and slaughter:

This method of eradication requires a reliable diagnostic test which can be applied on mass basis. The next step in stamping out the disease is immediate slaughter of all infected and exposed animals and their disposal by deep burial in quicklime or by burning. The premises and all possible contaminated objects and materials are then subjected to thorough cleaning and disinfection. In developed countries many of the major zoonoses such as tuberculosis, brucellosis, rabies and hydatid disease have been successfully eradicated by adopting test and slaughter policy.

Vector eradication:

The origin of the concept of vector eradication can be pinpointed to a paper written by Cooper Curtice of the US Bureau of animal Industry (BAI) in 1891, the first of a number of papers he wrote on the subject of tick eradication and he is known as "Father of tick eradication".

Mass immunization:

This technique has also been used in the regional eradication of a few infections such as small pox in humans.

The role of international organizations in prevention, control and eradication of zoonotic diseases:

World health organization (*WHO*):

In collaboration with its Regional Offices, WHO supports Member States in the surveillance and containment in humans and animals of zoonoses and foodborne zoonotic diseases of public health importance and animal diseases

with known or potential public health implications and in the surveillance and containment of resistance to antimicrobial agents in animals, with implications for human medicine. WHO Headquarters implements the activities through the Department of Communicable Diseases Control, Prevention and Eradication (CPE) in close collaboration with the Food Safety programme. The Mediterranean Zoonoses Control Centre (MZCC) based in Athens, Greece, is the coordinating and managing office for the Mediterranean Zoonoses Control Programme (MZCP). It is guided by WHO headquarters and collaborates closely with the WHO Regional Office for the Eastern Mediterranean. Other WHO programmes related to Zoonoses include Biologicals, Quality assurance and safety, Communicable Disease Surveillance and Response (CSR), Food Safety, Global Foodborne Infections Network (GFN), Rabies, Rab Net, rabies interactive and information mapping system and Water Sanitation and Health (WSH).

Food and agriculture organization (*FAO*):

The objective of FAO's Animal Production and Health Division (AGA) is to help and facilitate the development of the fast expanding and changing global livestock sector so as to enable it to provide clean and safe animal products to consumers. Emergency Prevention System for Animal Health (EMPRES-AH) is FAO's programme that deals with outbreak alerts. It continues to play a major role in the fight against persisting and/or spreading transboundry animal diseases at global level with emphasis on developing countries. A key component of EMPRES-AH is the Global Rinderpest Eradication Programme (GREP). Under the programme, large tracts of asia and Africa were freed from rinder pest (RP). The world's last confirmed case of RP was seen in 2001 in the Somali ecosystem.

World organisation for animal health (*OIE*):

The main objectives of the OIE are to ensure transparency in the global animal disease situation, to collect, analyse and disseminate scientific information, to provide expertise and to provide a better guarantee of the safety of food of animal origin.

Conclusion:

Prevention, control and eradication of zoonotic diseases are important especially in India because of approximately 70 per cent people are in close contact with domestic animals, where unhygienic living conditions, lack of education, poor personal hygiene, poor veterinary and public health services, poverty and malnourishment are prevailing that contribute to transmission of zoonotic diseases. Moreover, the increasing proximity between humans and animals and the continuous expansion of humans into their natural habitat is greater now than ever before. In the last few decades, zoonotic diseases across the world have increased in prevalence and have become a significant cause of infectious disease to humans. Various measures are being implemented across the world for prevention, control and eradication of zoonotic diseases but the emergence and re-emergence of zoonotic diseases are being continually increased mainly due to expansion in host, vector and geographical range. Therefore, to overcome from the problems of zoonotic diseases, it is essential to improve the basic public health infrastructure and public health measures, to improve the personal and environmental hygiene, creation of community awareness about potential risks from zoonotic diseases, co-operation between medical and veterinary sectors in diagnosis of zoonoses, exchange of information and organization of shared surveillance systems, only judicious use of antimicrobials in order to avoid antimicrobial resistance in zoonotic pathogens and strictly follow up of international regulations for travel and trade of animal and their products.

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