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Review on Epidemiology and Economic Importance of Foot and Mouth Disease in Ethiopia

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Abstract: Foot and mouth disease (FMD) is a highly contagious transboundary disease of all cloven-hoofed animals that can limit the trade of live animals and their products throughout the world. Globally FMD virus has seven different serotypes which are described as serotypes A, O, C, SAT1, SAT2, SAT3 and Asia1 that do not confer cross-immunity to each other. Among the seven serotypes of FMD, serotypes O, A, C, SAT 2 and SAT 1 were endemic and well-known distributed diseases in Ethiopia, but their level of prevalence and distribution may significantly vary across the different farming systems, years and agro-ecological zones of the country. The integrations of the host, agent and environmental factors are important for the occurrence of FMD. The last report of the occurrence of serotype C in Ethiopia was in 2005. The 5-years (2007-2012) record from NVI and NAHDIC shows FMD was caused by serotypes O, A, SAT 1 and SAT 2; the most dominant serotype was O followed by SAT 2. Districts that are characterized mainly by market-oriented cattle production such as Addis Ababa and Hawassa were more affected than districts with primarily subsistence systems. FMD causes economic losses, particularly to the dairy production, pig industries and draft power and high mortality in young animals and is a major constraint to international trade in live animals and their products. FMD outbreaks incur significant social and economic costs and affected countries are limited in their ability to trade with subsequent reduction in the value of their meat commodities. Therefore, Awareness creation in the community about the disease and the role of vaccines, further study of wildlife on the epidemiology of FMD and implementation of strict animal movement control should be considered during the control program.

Key words: Epidemiology · Ethiopia · FMD · Risk Factors · Serotype

INTRODUCTION

Livestock production is one of the most principal means to achieve better living standards in many regions of the developing world. The national economies and the livelihood of rural communities in sub-Saharan African countries like Ethiopia are largely dependent on livestock production. Ethiopia has the largest livestock population in Africa, with 65 million cattle, 40 million sheep, 51 million goats, 8 million camels and 49 million chickens [1]. Livestock is a major source of animal protein, power for crop cultivation, means of transportation, export commodities, manure for farmland and household energy and means of wealth accumulation. The sector contributed up to 40% of agricultural Gross Domestic Product (GDP), nearly 20% of total GDP and 20% of national foreign exchange earnings [2].

Despite the largest livestock population in Ethiopia, livestock diseases are the major constraint of productivity and production causing economic losses to livestock producers in Ethiopia [3, 4]. Foot and mouth disease (FMD) is a highly contagious transboundary disease of all cloven hoofed animals that can limit the trade of animals and animal products throughout the world [4-6]. Globally the FMD virus has seven antigenically different serotypes which are described as serotypes A, O, C, SAT1, SAT2, SAT3 and Asia1 that do not confer cross-immunity to each other. Within each serotype, many strains can be identified by genetic and immunological tests [7]. Serotypes O and A are widely distributed, whereas serotypes SAT 1, SAT 2 and SAT 3 are normally restricted to Africa [8].

In Ethiopia Serotypes O, A and C were first recorded by Food and Agricultural Organization (FAO) and World

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Reference Laboratory (WRL) during the period of 1957 to 1979 [9]. FMD disease outbreaks in Ethiopia as serotype O, A and SAT-2 were also reported by Sahle *et al.* [10]. Serotype O was the dominant type which causes a considerable economic loss of the rural communities. FMD serotypes O, A, C, SAT 2 and SAT 1 were identified in Ethiopia. Serotype O was the dominant outbreak followed by SAT 2 [11, 12]. The last report of occurrence of serotype C in Ethiopia was in 2005 [13].

The etiologic agent of FMD is a single stranded RNA virus which belongs to the genus *Aphthovirus* and family *Picornaviridae*. It is widely accepted that the most mechanism of FMD transmission is through physical contact between infected and susceptible animals [14]. Airborne FMDV transmission can result from a large number of infected pigs, resulting in plumes of aerosolized virus in the atmosphere. The host, agent and environment are important risk factors for the occurrence of FMD in susceptible animals [15]. FMD is characterized by development of vesicles, which soon rupture leaving erosions, in the mouth, including the tongue (but not the ventral surface of the tongue) and at the skin-hoof junction of the feet. Affected animals develop fever, loss of appetite and the milk production of dairy cows declines sharply. In sheep and goats, lesions may be small and unnoticeable making these species dangerous source of infection [16].

Globally, there is great difference in progress towards FMD control and eradication. Some countries are either FMD free or well on the road to achieving freedom; others are at an early stage of FMD control. Recently, there has been international endorsement of a progressive control pathway for FMD and this has stimulated new national and regional efforts to control the disease [7]. The control and prevention of FMD depends on prevention of the introduction of virus (animal movement restriction) and vaccination in endemic area. In countries where the disease is endemic, or where there are wildlife reservoirs, eradication is seldom practicable. For countries in large continents, international cooperation is required for eradication [15].

Foot and mouth disease causes high economic loss in developing countries like Ethiopia where the livelihood of most of the people depends directly on livestock. This impact may be direct or indirect. Production losses and changes in herd structure are a direct impact whereas impacts due to FMD control costs, limited access to the market and limited use of new production technologies are the indirect impacts of FMD [17]. FMD impacts in terms of visible production losses and vaccination in endemic countries can cause losses of >USD 1.5 billion per year [17]. In Ethiopia FMD is posing a major threat thereby causing substantial economic losses through morbidity and mortality [18]. According to Jemberu *et al.* [12] the total annual losses due to FMD estimated based on production losses, export losses and control costs to be greater than 1350 million Birr and the major cost is due to production losses. Therefore, the objective of this paper is to review the current situation of the epidemiology and economic importance of FMD in Ethiopia.

Etiology: FMD virus is a single-stranded, non-segmented, positive sense RNA virus that belongs to the genus *Aphthovirus* of the family *Picornaviridae*. There are seven FMDV serotypes types A, O, C, Asia 1 and South African Territories SAT 1, SAT 2 and SAT 3. Within these serotypes, more than 60 strains have been identified [19].

Geographical Distribution: The serotypes of FMDV are not distributed uniformly around the world. The serotype O, A and C viruses have had the widest distribution and have been responsible for outbreaks in Europe, America, Asia and Africa. The SAT1, 2 and 3 viruses are normally restricted to sub-Saharan Africa. However, there have been some limited outbreaks due to SAT1 viruses in the Middle East between 1962–1965 and 1969–1970 and then in Greece in 1962 [20]. Similarly, there have been reports of minor incursions of the serotype SAT2 in Yemen in 1990 and in Kuwait and Saudi Arabia in 2000. More recently, FMD outbreaks due to serotype SAT2 spread from sub-Saharan Africa through northern African countries (Egypt and Libya) and into Palestine [21, 22]. The occurrence of serotype C has been declining during the last 30 years and its distribution has become very limited in the recent decade; the last reported occurrence of serotype C was in 2004 and 2005 in Kenya and Ethiopia respectively [13]. Among the seven serotypes of FMDV, serotype O, A, SAT 2 and SAT 1 have been reported in Ethiopia in recent times [23].

Table 1: Serotypes of FMD commonly isolated from certain geographical regions

Region	Virus Serotype
South America	A, O, C
Europe (Historically)	A, O, C
Africa	O, A, C, SAT1, SAT2, SAT3
Asia	A, O, C, Asia1

Source: [24]

Mode of Transmission: The predominant route of FMD virus infection is respiratory tract, although ingestion of contaminated food or direct inoculation also both highly effective in transmitting infection. Transmission can occur by contact, aerosols, mechanical carriage, humans or vehicles, on fomites and through animal products. Virus may be recovered from all body secretion (tears, nasal, saliva, urine, feces, milk, vaginal, semen and the placenta of aborted fetus). The survival of virus in such excretions depends up on temperature, PH and humidity [25, 26]. Occasionally there is transmission between carrier buffalo and susceptible individuals [14]. Airborne FMDV transmission can result from a large number of infected pigs, resulting in plumes of aerosolized virus in the atmosphere. Under specific climate conditions (particularly downwind), aerosolized FMDV produced by infected pigs can travel a significant distance infecting cattle from 20 km up to 300 km and infecting sheep from 10–100 km away [27].

Risk Factors: The integrations of host, agent and environmental factors are important for the occurrence of FMD. Cattle and pigs are more susceptible, but goats, sheep, buffalo and other cloven hoofed wildlife (play a great role as reservoirs of infection for domestic animals which is difficult to eradicate the disease as well as important for disease control when an outbreak is occurred) are also developing a mild symptomatic disease. Immature animals are relatively more susceptible. FMD virus is resistant to external influences including common disinfectants and the usual storage practices of meat trade. It may persist over one year in infected premises, for 10-12 weeks on clothes and feeds. The virus can survive in dry fecal material for 14 days in summer and for 6 months in winter. It can also survive in urine for 3 days in summer and 28 days in winter. Under favorable condition of low temperature, high humidity, moderate wind and comfortable topography, the virus in aerosols may spread for long distance [15, 28, 29].

Pathogenesis: In cattle the most consistently infected tissues are the epithelia of the naso-pharynx and larynx. The tissues of the naso-pharynx and FMD viruses have a complex relationship. The naso-pharynx is also the site of viral persistence in chronically infected animals (carriers animals). Vesicle formation, cell lysis and significant inflammation occur at secondary replication sites (oral mucosa, skin of the horn-hoof junction and skin of the teats). The cells which support viral replication are located in the basal layer of naso-pharyngeal epithelium. However, the mechanism by which viral replication occurs in the naso-pharyngeal epithelium without causing cell lysis is unknown. The recently infected animals may contain high levels of antibody (mainly IgA) directed against the infecting virus. In pigs, delayed clearance of viral RNA from pharyngeal and lymphoid tissues has been observed but that has not been shown for infectious virus [16].

Clinical Signs: Foot and mouth disease is characterized by development of vesicles, which soon rupture leaving erosions, in the mouth, including the tongue (but not the ventral surface of the tongue) and at the skin-hoof junction of the feet. However, before that occurs, affected animals develop fever, lose their appetite and the milk production of dairy cows declines sharply. In sheep and goats, lesions may be small and unnoticeable making these species dangerous source of infection [29, 30]. Affected animals may lie down continuously, evidence of pain when walking or show lameness in one or more legs. The lesions in the mouth frequently result in salivation and grinding of the teeth or 'lip smacking'. Abortion may result from infection with FMD viruses and is thought to occur more frequently in sheep than other species [16].

Diagnosis

Clinical Signs: In cattle and pigs the clinical diagnosis of FMD is usually not difficult because the signs and lesions are characteristic and consistent. However, in sheep and goats, clinical diagnosis may be difficult because the signs are often less pronounced or even unapparent [16].

Serological Tests: Enzyme-linked immunosorbent assay (ELISA) is an important serological test to diagnose the FMD virus. Dilution of samples to be tested and controls are incubated in the wells of the antigen-coated plate. Any antibody specific to 3 ABC antigen binds to the wells and forms an antigen-antibody complex on the plate well surface. Unbound material is removed from the wells by washing. A peroxidase-labeled anti-Ig-G Conjugate is added which binds to the antibodies of the sample and formed a complement with 3ABC antigen. Unbound conjugate is removed by washing and the TMB- containing substrate is added to the wells. The degree of color, which develops, is directly proportional to the amount of antibody specific present in the sample for the 3ABC [31].

Complement Fixation Test (CFT): CFT is used to indicate the presence of antibodies to FMD virus. Complement will combine (be fixed) with an antigen. If all the complements are fixed in the complement fixation stage, then none

Table 2: Differentiation of vesicular diseases

Animal species	FMD	Vesicular stomatitis	Vesicular exanthema	Swine vesicular disease
Cattle	+	+	-	-
Pig	+	+	+	+
Sheep and Goat	+	+ or -	-	-
Horse	-	+	-	-

Source: [35]

remain to cause hemolysis of the red blood cells in the indicator stage. For positive test results all available complement is fixed by the antigen-antibody reaction; no hemolysis occurs, so the test is positive for the presences of antibodies. For negative Test result, No antigen –antibody reaction occurs. The complement remains and the red blood cells are lysed in the indicator stage, so the test is negative [32].

Identification of the Agent in Tissue Fluid: The best source of material for isolation and characterization of FMD virus involved is fragments of epithelium from freshly ruptured vesicles in the mouths or on the feet of affected animals. These are only available for a day or two days following rupture of the vesicle, as a result acute cases are the best source of diagnostic material [33].

Polymerase Chain Reaction (PCR): The PCR techniques are increasingly used for rapid identification of FMD virus and sequence analysis of any PCR positive. The reverse-transcription PCR (RT-PCR) can be used to amplify the genome fragment of FMD virus in diagnostic material. Specific primers have been designed between each of the seven serotypes [34].

Differential Diagnosis: Due to the economic and political significance of FMD, it should be differentiated from another vesicular diseases such as vesicular stomatitis, swine vesicular disease and vesicular exanthema (Table 2).

Treatment: No treatment exists for FMD virus. However, proper animal husbandry practices and treatment of secondary bacterial infection and dressing to inflamed areas to prevent secondary infection is recommended in endemic countries where slaughter policy is not enforced. Sick animals may be treated topically with mild disinfectants but also by applying broad-spectrum antibiotics parentally, tetracycline in particular, in order to control the consequences of secondary bacterial infections [15, 25].

Control and Prevention: FMD is subject to national and international control and the measures taken depend on whether the country is free from the disease or subjected to sporadic outbreaks or has endemic infection. Countries free of FMD impose strict import regulation on animals, animal products and potentially contaminated materials from FMD endemic countries. Quarantine and vaccination programs are also used to control outbreaks and to prevent spread of the disease [26]. In countries where the disease is endemic, efforts are generally directed at protecting high yielding dairy cattle by a combination of vaccination and control of animal movement [25].

Preventive measures in the absence of disease should be implemented as control of national borders to regulate or prevent significant movement of animals and livestock products from non-free neighbors or trade partners. For free countries, prohibitions of imports of animals and livestock products from non free countries are important preventive measures. Emergency measures in the event of outbreaks such as rapid slaughter of infected animals, in contact animals and herds “stamping-out” followed by cleaning and disinfection is important to reduce the risk of re-infection. Intensive investigations to determine if infection is likely to have spread to additional locations within or outside of the protection and surveillance zones and containment measures for such herds or villages, depending on the risk identified. And also possible emergency vaccination is important [15, 36, 37].

In Ethiopia the control of FMD is practiced by involvement of quarantine, restriction of animal movement, isolation of infected animals, vaccination programs, proper disposal of infected carcass and other methods which are feasible to Ethiopian economy. Currently there is no country-wide vaccination program aimed to control FMD and a ring vaccination is carried out around an infected area. Considering the wide prevalence of serotypes O and A, the National Veterinary Institute (NVI) is producing an inactivated vaccine [38].

Epidemiology of Fmd in Ethiopia: Foot and Mouth Disease have a major socioeconomic impact in developing countries both at macroeconomic and household levels [39]. The impact of the disease could be significant in Ethiopia where livestock, particularly cattle (which constitute about 71% of the total livestock biomass) play multiple roles in the household and national economies. In addition to the conventional meat and milk products, cattle provide about 80% of draft power for the crop agriculture, manure for soil fertilizer and cooking fuel and serve various social networking functions [40, 41]. Livestock is also an important foreign currency earning resource for the national economy through export of meat and live animals [42].

In Ethiopia there are large numbers of susceptible domestic and wild ruminants [43]. FMD is an endemic and well known wider distributed disease in Ethiopia, but its level of prevalence and distribution may have significantly vary across the different farming system and agro- ecological zones of the country and frequently occur in the pastoral herds of the country [38, 44, 45]. The disease in cattle was first recorded by Food and Agricultural Organization (FAO) and World Reference Laboratory (WRL) as FMD serotypes O, A and C during the period of 1957 to 1979 [9].

The World Reference Laboratory at Pirbright reported FMD disease outbreaks in Ethiopia as serotype O, A and SAT-2 in the time period between1990 to 1999. During that time serotype O remains the dominant and causes a considerable economic loss of the rural communities. The incidence of FMD in Ethiopia has increased between 1.3 to 1.5 times since 1990. [10].

The SAT 2 was first reported in 1989 in Borena region of southern Ethiopia [46]. The SAT 1 and 2 serotypes were diagnosed relatively recently in Ethiopia and both of them were first detected in the south and southwest parts of the country. These serotypes still have not been diagnosed in the northern half of the country (north of North Showa). A previous serological study also indicated that SAT viruses had been limited to southern Ethiopia (Borena and Southern Showa zones) [10]. Movement restriction during outbreaks should therefore limit the spread of these serotypes further to the north of the country. The other implication of this serotype distribution is the directed use of vaccine serotypes in different parts of the country to minimize the cost of vaccination that arise due to inclusion of additional serotypes.

In the year 2000 – 2006 there were 215 FMD outbreaks in the country and the highest outbreaks occurred in 2001 with 88 outbreaks [40]. According to NVI report, of the total samples examined from the outbreak, the serotypes identified were serotype O, A, C, SAT2 and SAT 1. Serotype O was the dominant outbreak with 73.93% rate, while serotype A (19.68%), C (1.59%) and SAT 2 (4.79%) rate were detected [11]. Serotype O was also the dominant outbreak followed by SAT2 in Ada Veterinary Clinic and in Central Areas of Ethiopia [47, 48]. In contrast to the above findings only serotype O was recorded throughout Ethiopia where FMD outbreaks occurred [49]. The last report of occurrence of serotype C in Ethiopia was in 2005 [13].

Districts that are characterized mainly by market oriented cattle production such as Addis Ababa and Hawassa were more affected than districts with primarily subsistence systems. In these districts, the presence of the disease was reported almost every year. Similarly, FMD outbreaks have been reported to occur every year in Bishoftu town in central Ethiopia, where urban dairying is abundantly practiced [50].

The higher incidence of FMD in these urban towns could be associated with improved exotic breed's production system. Improved dairy cattle breeds are very susceptible to FMD and are even difficult to protect by frequent vaccination [28]. In urban and semi- urban areas of country there is a high livestock marketing activity especially during holidays through which infections are introduced and spread [12].

In Ethiopia there are an association between national parks and FMD outbreaks. SAT serotypes were first reported in the southern and southwestern Ethiopia (Omo and Gambella national parks) where national parks with buffalo (the only true serological reactors to FMD) populations were found [10]. However there were incidence of non-SAT serotype viruses in limited geographical area where buffalos are present [12].

National disease outbreak investigation records from NVI and NAHDIC showed that FMD outbreaks that occurred in the 5-year period (2007-2012) were caused by serotypes O, A, SAT 1 and SAT 2. The most dominant serotype was O accounting for 70% and it occurred frequently, distributed widely in Ethiopia. During the studied period the second most dominant serotype was serotype SAT 2 (serotype SAT 2 has overtaken the rank of serotype A, which was reported as the second most dominant serotype in the country as stated in [43, 51],

which was occurred frequently in the country. The period was also a time in which the newest serotype, SAT 1, was isolated for the first time in the country in 2007 from an outbreak in southwest Ethiopia [12].

Economic Importance of Fmd in Ethiopia: FMD causes production losses, particularly to the dairy production, pig industries and draft power and high mortality in young animals and is a major constraint to international trade in live animals and their products. The impact of disease is not equal across all countries and livestock populations due to differences in the genetics of the livestock, the management of the livestock, prices for the livestock systems inputs and outputs and their ability to supply livestock for export markets [17]. The losses are more pronounced in cattle and pig production systems; the impact in goat and sheep production systems is generally low. The effects are also much more dramatic in intensive systems of cattle and pigs; in particular FMD can cause devastating losses in dairy and in intensive pig production systems. However, the impact of the disease in extensive cattle systems is small and the incentives to control the disease are also small [52]. FMD out breaks incur significant social and economic costs and affected countries are limited in their ability to trade with subsequent reduction in the value of their meat commodities [53].

Direct Economic Impact: Direct production losses due to FMD include reduced milk production affecting both the humans and calves [54]. Although FMD has a short term affect on an animal's health, chronic FMD typically reduces milk yields by 80% [54, 55]. Livestock growth rates are also suppressed and mortality amongst young stock is 2–3% [56] although occasionally much higher [55, 57]. Loss of traction power where draught animals are used is particularly damaging if it occurs during harvest [58, 59]. Visible production losses are most prominent in pigs in intensive production systems and dairy cattle [60]. A compound effect of fertility problems due to abortion and reduced conception rates is a need to have a greater proportion of breeding animals in a population for a given output. This invisible loss means that for every kilo of meat or milk produced there is an additional fixed cost to maintain more breeding stock [17].

Indirect Economic Impact: Indirect economic impact of FMD is the cost of vaccination, outbreak control, culling and compensation. In addition, significant amounts are spent by the private sector. These costs are enormous with an estimated 2.35 billion doses of FMD vaccine administered in the world every year at a cost of $0.4–3 or occasionally $9 per dose including delivery and application [18, 54, 61, 62]. Even if a country is FMD-free there are ongoing costs due to efforts to prevent disease introduction, including import controls and sometimes vaccination. In addition, maintaining FMD early detection and control capability, including vaccine banks, is costly. The cost of research and surveillance has significant cost, for instance, >3 million serum samples were tested after the UK 2001 outbreak [63].

FMD is a highly contagious transboundary disease affecting many species and is not easily contained within one country or one population, Countries infected with FMD cannot trade live animals with FMD-free countries. Countries with the best meat prices are FMD-free (i.e. EU, USA and Japan) [64] where prices are typically 50% higher [59]. The trade of livestock products is also restricted. If regular outbreaks occur only processed, tinned products can be exported to free countries; if FMD is effectively controlled with vaccination then deboned meat can be exported [65].

CONCLUSION AND RECOMMENDATIONS

FMD is one of the most economically and socially devastating cloven-hoofed animal diseases affecting animal production throughout the world. The virus has seven serotypes (A, O, C and Asia 1, Sat 1, Sat 2 and Sat 3). Serotypes O, A, C, SAT2 and SAT1 are prevalent in Ethiopia. The incidence of the disease is high in urban districts where there is market-oriented cattle production and there is a high movement of animals during holidays. FMD outbreaks incur significant social and economic costs and limit the trade of live animals and animal products. It reduces milk yields, suppressed livestock growth rates, causes fertility problems due to abortion and reduces conception rates. It has also indirect costs such as the cost of vaccination, outbreak control, culling, compensation research and surveillance. Therefore based on this conclusion, the following recommendations are forwarded:

- Implementing strict animal movement control across international boundaries to limit the introduction of new serotypes.

- Awareness creation in the community about the disease and the role of vaccines.
- The role of wildlife in the epidemiology of FMD should be further studied and considered during the control program.
- Quarantine of infected farms should be practiced through awareness creation
- Market-oriented production in the urban and semi-urban areas can be targeted for intensive FMD control.

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