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Response to Rift Valley Fever in Tanzania: Challenges and Opportunities

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Abstract: Rift Valley Fever (RVF) is an arthropod borne viral disease affecting livestock (cattle, sheep, goats and camels), wildlife and humans caused by *Phlebovirus*. The disease occurs in periodic cycles of 4-15 years associated with flooding from unusually high precipitations in many flood-prone habitats. *Aedes* and *Culex* spp and other mosquito species are important epidemic vectors. Because of poor living conditions and lack of knowledge on the pathogenesis of RVF, nomadic pastoralists and agro-pastoralists are at high risk of contracting the disease during epidemics. RVF is a professional hazard for health and livestock workers because of poor biosafety measures in routine activities including lack of proper Personal Protective Equipment (PPE). Direct exposure to infected animals can occur during handling and slaughter or through veterinary and obstetric procedures or handling of specimens in laboratory. The episodic nature of the disease creates special challenges for its mitigation and control and many of the epidemics happen when the governments are not prepared and have limited resource to contain the disease at source. Since its first description in 1930s Tanzania has recorded six epidemics, three of which were after independence in 1961. However, the 2007 epidemic was the most notable and wide spread with fatal human cases among pastoralists and agro-pastoralists concurrent with high livestock mortality. Given all the knowledge that exist on the epidemiology of the disease, still the 2006/2007 epidemic occurred when the government of Tanzania was not prepared to contain the disease at source. This paper reviews the epidemiology, reporting and outbreak investigation, public awareness, preparedness plans and policy as well as challenges for its control in Tanzania.

Keywords: Rift valley fever, *Phlebovirus,* high precipitations, livestock, mosquitoes, pastoralists, Tanzania

Introduction

Rift Valley Fever (RVF) is a multi-host arthropod-borne viral haemorrhagic disease affecting livestock, humans and occasionally wildlife, mostly in Africa (Harper, 2004; Evans *et al.,* 2008; Sang *et al.,* 2010). RVF is an acute, febrile disease accompanied by a wave of abortion and perinatal mortality in livestock (sheep, goats, cattle, and camel). The disease is caused by *Phlebovirus,* an RNA virus of the family *Bunyaviridae* and is associated with periodic outbreaks. The virus is transmitted by mosquitoes (*Aedes*, *Culex* spp) and other blood sucking insects such as the sand fly of the *Phlebotomus* species (Jup *et al.,* 2002; Harper, 2004; Flick & Bouloy, 2005; Amwanyi *et al.,* 2010; Sang *et al*., 2010). In humans it is a febrile (38 to 39.5^{O}C) or influenza like illness that can be associated with, severe headaches, muscle and joint pains, anorexia, high respiration rate, vomiting, diarrhoea, hepatitis, jaundice, marked leucopoenia and extreme eye pain with sensitivity to light (photophobia). Few severe fatal haemorrhagic syndrome cases have occurred in humans as a consequence of hepatic necrosis, myocarditis, retinitis and/or encephalitis (Daubney *et al.,* 1931; Harper, 2004; Mohammed *et al.,* 2010; Munyua *et al.,* 2010). In livestock the clinical signs include anorexia, high temperature (up to 40^{O}C), blood-stained nasal and lachrymal discharges, a high respiration rate, prostration, lateral recumbence with opisthotonous, respiratory distress and death (Davies & Martin, 2003). Exotic breeds are more susceptible to RVF infection than indigenous sheep, goats and cattle, and recovering animals from RVF develop life- long immunity.

Recent entomological investigations to determine the epidemic vectors of RVF have identified 10 mosquito species, including *Aedes circumluteolus, A. ochraceus, A. pembaensis*, *Anopheles squamosus*, *Culex paicilipes, Cx bitaeniorhynchus, Cx univittatus, Mansonia africana* and *M. uniformis* (Sang *et al.,* 2010). Flooding of mosquito habitats can introduce Rift Valley Fever Virus (RVFV) into domestic animal

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populations by production of infected *Aedes* mosquitoes while epizootic/ epidemic cycles are driven by the subsequent elevation of various *Culex* mosquito populations, which serve as secondary vectors if mosquito habitats remain flooded long enough (Linthicum *et al.,* 1999; Amwanyi *et al.,* 2010). Aedes mosquitoes are also capable of trans-ovarial transmission of the virus to offspring leading to synchronous new generations of infected mosquitoes hatching from eggs (Linthicum *et al.,* 1999; Amwanyi *et al.,* 2010). This accounts for the continued presence of the RVF virus in enzootic foci and provides the virus with a sustainable mechanism of existence as the eggs of these mosquitoes can survive for several years in dry conditions. Infected mosquitoes can be transported for long distances in low-level wind or air currents, which may lead to the rapid spread of the virus from region to region or even internationally (Sang *et al.,* 2010). The role of wildlife in the epidemiology of RVF is not known due to lack of enough resource to conduct research in wildlife in Tanzania. The objective of this review is to describe the epidemiology, outbreak reporting, public awareness, preparedness plans and policy, and challenges for its control in Tanzania.

Occurrence of RVF and risk factors

The disease was first recognized and characterized in the Great Rift Valley of Kenya in 1913, hence its name (Daubney *et al.,* 1931; Sang *et al.,* 2010). However, since the 1930s when it was first described, the understanding for the epidemiology and diagnostic capabilities have progressed a great deal. In the 1930s the causal agent was only described as a Bunyammwera-like virus but later on it was clearly known as a *Phlebovirus* (Harper, 2004). RVF had been frequently occurring in Kenya with a major epidemic in 1950-1951, which resulted in the death of an estimated 100,000 sheep (Shieh *et al*., 2010). In Tanzania the epidemics occurred in 1930s, 1947, 1957, 1977, 1997 and 2006/2007 (FAO, 1999; NASA, 2002; WHO, 2007). Therefore, since independence Tanzania has recorded three epidemics, however the most notable one was in 2006/2007. The 1997 epidemic in East Africa occurred after exceptionally high precipitation (*El Nino*), which resulted in the death of at least 300 people and large numbers of animals in remote parts of Northern and southern Kenya and southern Somalia (Munyua *et al.,* 2010; Shieh *et al.,* 2010). However, in Tanzania it was mild and had little pathologic effect to livestock and was confined in the northern zone with no confirmed human cases. The major risk factors associated with human cases in nomadic pastoral and agro-pastoral communities are contact with sick animals and animal products including blood, meat and milk (Mohammed *et al.,* 2010). High precipitation with flooding in areas of high density of livestock creates a conducive environment for RVF outbreak (Nguku *et al.,* 2010).

Detection of immunoglobulin G (IgG) antibodies against RVF by Enzyme Linked Immunosorbent Assay (ELISA) indicates previous exposure to the virus while detection of immunoglobulin M (IgM) indicates recent infection (Paweska *et al.,* 2005). Confirmation of RVF is by, detection of viral RNA by real-time reverse transcriptase polymerase chain reaction (RT-PCR) or detection of viral antigens in liver tissue biopsies by immunohistochemistry, demonstration of viral antigens in hepatocytes and Kupffer cells by immunoperoxidase assay, and histologically by demonstration of extensive hepatocellular necrosis with acidophilic materials in cytoplasm (Arborio & Hall, 1989; Van der Lugt *et al.,* 1996; Mohammed *et al.,* 2010; Shieh *et al.,* 2010). Severe RVF infection in humans can persist for an average of more than 30 days before recovery or death with more than 80% of the patients exhibiting high rate of encephalopathy (Mohammed *et al.,* 2010). Outbreak detection, etiologic confirmation and public health responses in 2006/ 2007 epidemic in Kenya and Tanzania were made possible by advances in communication, diagnostic technologies like RT-PCR and local diagnostic capacity (Breiman *et al.,* 2010; Nguku *et al.,* 2010). However, in Tanzania, the impeding factor in containing the disease at source was poor inter-Ministerial collaboration and limited resources to execute control activities.

RVF virus is cytopathic and tends to target the liver causing focal hepatic necrosis and in brain causing necrotic encephalitis (Harper, 2004; Shieh *et al.,* 2010). Extensive diffuse hepatocellular necrosis without prominent inflammatory cell infiltration in liver tissues is pathognomonic for RVFV (Shieh *et al.,* 2010). This histopathological change is consistent with immunohistochemistry and is an important differential diagnosis of RVF against other haemorrhagic fevers e.g. yellow fever, Ebola, Crimean-Congo hemorrhagic fever, Lassa fever virus, and Marburg virus (Coetzer, 1982; Shieh *et al.,* 2010). The lytic

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virus-cell interaction in liver which involves direct virus-induced hepatic cell necrosis is the major pathogenesis of RVFV infection (van der Lugt *et al.,* 1996; Shieh *et al.,* 2010). Genetic analysis of selected regions of virus S, L, and M RNA genome segments indicate little genetic variation among viruses associated with disease, and even the Saudi Arabia and Yemen viruses were identical to the isolates from East Africa of 1997 (Shoemaker *et al.,* 2002; Balkhy & Memish, 2003).

Limited resources lead to inadequate surveillance in livestock and the severity of RVF epidemic is normally exacerbated by delays in recognizing risk factors and taking decisions to prevent and control the disease (ILRI, 2008; Munyua *et al.,* 2010). Contact with animal body fluids, sheltering livestock inside the home, consumption of products from sick animals and to a lesser extent being a herdsperson are the main risk factors associated with RVF infection (Frank & Jeffrey, 2001; Woods *et al.,* 2002; Amwanyi *et al.,* 2010).

Outbreak reporting and routine surveillance

Timely outbreak response requires effective early warning and surveillance systems. Previous evidence points out the important role that livestock keepers can play in veterinary surveillance (Mariner & Paskin, 2000; Grace *et al.,* 2008). Pastoralists are normally aware of the unusually heavy nature of the rains and flooding, notice mosquito swarms that are unusual because of their intensity and the physical characteristics of the species involved (*Aedes* spp.), and associate with unusually high morbidity and mortality in their flocks consistent with RVF (Linthicum *et al.,* 1999; Woods *et al.,* 2002). These facts were common knowledge among livestock owners well in advance of the detection of RVF by veterinary service surveillance systems. They also noted human cases consistent with RVF well in advance of detection by the public health surveillance system (Breiman *et al.,* 2010; Anyamba *et al.,* 2010). This suggests that veterinary surveillance systems could detect RVF outbreaks earlier by taking advantage of livestock owner observations through the integration of active syndromic surveillance, such as participatory disease surveillance (PDS) geared to the level of outbreak probability (Mariner & Paskin, 2000)

Using the NASA Meteorological information, early warning exists to predict the possible location of RVF epidemic (Harper, 2004; Breiman *et al.,* 2010). Rainfall data is therefore a useful predictive tool for epizootic RVF, either by actual recording or from data derived from Remote Sensing Satellite Imagery Data (RSSD). The monthly analysis of this data in the region is valuable for risk assessment of RVF virus activity. Currently, FAO/EMPRES, IGAD, Climatic Prediction and Application Centre (CPAC) and other regional and national meteorological centres are carrying out the analysis on a monthly basis. The US Department of Defence "Global Emerging Infections Surveillance and Response Systems" (GEIS) gives early warning for RVF (URT, 2010).

The forecast model used in 2006/7 incorporated data on vegetation changes (normalized difference vegetation index, NDVI) that occurred only after conditions were in place for an RVF outbreak (Davies & Martin, 2003; Clements *et al.,* 2007; Sang *et al.,* 2010). The immune status of animals, herd movements and local conditions favouring the reproduction of mosquitoes play a more significant role in the inter-annual variability of RVF outbreaks. The occurrence of RVF can be endemic or epidemic, depending on the climatic and vegetation characteristics of the regions. African agro-climatic zones can be used as a good guide of RVF virus activity: (i) endemic activities (+/-cryptic RVF) in high rainfall forests and forest edges; (ii) periodic increased RVF-virus activity to epidemic proportions in bushed and wooded grasslands following long standing floods; (iii) rare but explosive epidemics in dry grassland and semi-arid zones if associated with heavy seasonal rainfall and floods.

In response to initial warnings, national stakeholders could reinforce local climate monitoring and disease surveillance in known high risk areas, and alert response systems to begin preliminary mobilization of resources (Clements *et al.,* 2007; ILRI/FAO, 2009).

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RVF awareness among scientists and the lay community

Limited awareness about RVF is one of the factors explaining limited and uncoordinated response to RVF outbreaks. Awareness about RVF signs and its clinical manifestations and knowledge on early warning is still low among lay community members particularly agro-pastoral communities (Jost *et al.,* 2010). Studies have shown that the knowledge of pastoral communities on risk practices including eating raw meat, raw milk, touching and herding aborted animals and consuming products from such animals is still limited (Amwayi *et al.,* 2010). In a recent survey regarding awareness among agro-pastoral and pastoral communities in Serengeti ecosystem has shown that only 5.3% of the community members were aware of zoonotic risk of RVF (R. Fyumagwa unpubl.). In the 2007 RVF epidemic, the Maasai of northern Tanzania had low levels of traditional knowledge concerning livestock diseases (Jost *et al.,* 2010). It is argued that the Maasai now have less ability to utilize indigenous knowledge on diseases due to dependence on ecotourism and crop cultivation for their livelihoods, and have greater access to veterinary services (Jost *et al.,* 2010). However, as RVF happens in cycles of 4 to 15 years it is difficult for them to recognize the start of an RVF outbreak. Moreover, it is difficult to differentiate RVF from tick-borne diseases, which are the number one killer of livestock in East and Central Africa (Fyumagwa *et al.,* 2007; 2011).

The medical and veterinary personnel on the other hand were aware about the RVF epidemic, as evidenced by how they handled the first index cases abiding with biosafety precautions despite limited resources (Mohammed *et al.,* 2010). Despite the high infection rate of about 309 human cases with 142 fatal cases (46%) and a mortality of 16,973 cattle, 20,193 goats and 12,124 sheep, no medical or veterinary personnel were reported to have contracted the infection (MLDF, 2008; Mohammed *et al.,* 2010). Health education campaigns using media to prevent transmission of the RVF virus through handling or consumption of infected animals were implemented including narratives explaining "do not slaughter, skin, milk or provide obstetrical procedures to sick animals, bury or burn carcasses during an outbreak, boil milk, wear personal protective equipment (PPE) such as gloves, overalls, boots, eyewear, and mask when handling sick animals and products, avoid contact with infected tissues, blood, milk, meat aborted foetuses and sick animals" (Amwanyi *et al.,* 2010).

Preparedness plans, policy and institutional environment on RVF

Tanzania has developed an emergency preparedness plan for RVF whose implementation has taken into consideration the existing policy reforms, public sector reforms, liberalization of trade, privatization of health and animal health service delivery and decentralization. Health policy includes Health Sector Strategic Plan III (HSSP III), Health Sector Policy and Health Sector Reforms which are in line with the National Livestock Policy of 2006 (URT, 2010). All policies recognize RVF as a Transboundary Animal Disease (TAD) and a zoonotic disease with socio-economic and public health significance and therefore aim to control and prevent, in order to protect animal and human health, sustain the livestock industry and stimulate trade. The plan is guided by the Disaster Management Policy of 2004 with regard to prevention, preparedness, response and recovery from RVF outbreak and the disease was declared a national disaster in 2007. The Department of Disaster Management under the Prime Minister's Office is responsible for resource mobilization, coordination and management of the emergency preparedness plan.

According to Disaster Management Policy and the National Operational Guidelines, the Lead Ministries are those responsible for animal health, human health and wildlife. In complementing this plan other relevant Ministries and Institutions are responsible for implementing their respective roles as stipulated in the document. Networking in RVF surveillance will ensure that a dialogue with local traders and international trading partners is maintained in order to make sure that they are aware of the RVF risk status and the need to support National Rift Valley Fever Emergency Preparedness and Response Plan (RVF-EPRP). The realization of this objective depends on individuals and institutions whose activities relate to medical, veterinary and wildlife services (URT, 2010).

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Retrospective data from 1912 shows recurrence of disease in the same locations suggesting that targeted control measures such as livestock vaccinations in high risk areas before the onset of the outbreak can minimize the impact of the disease (Sang *et al.,* 2010). Unfortunately, none of the countries at risk had ever put in place preparedness plans since the disease was described to be a mosquito-borne viral infection in 1930s. Even in the recent outbreak of 2006/ 2007 the affected East African countries did not have contingency plans for response to RVF when FAO issued an alert on a possible outbreak. Due to delays in implementation on response activities, the efforts made in providing vaccination to livestock at risk did not contribute much in preventing the spread of the disease (Jost *et al.,* 2010; Munyua *et al.,* 2010). The preparation of NRVF-EPRP in Tanzania is the commitment to strengthen emergency preparedness and response against possible re-occurrence and spread of RVF. In addition Tanzania has established the Zoonotic Diseases Emergencies Task Force (ZDETF) which has the responsibility of controlling all zoonotic diseases disasters. For the RVF-EPRP to be effective there must be a mechanism of controlling livestock movement including defined stock routes and animals must be branded to facilitate traceability. However, 50 years after independence, Tanzania has done very little to develop proper land use plans and the vast land is still owned by the state. The existing communal land tenure system makes it difficult to control livestock movement, hence is practically very difficult to contain the disease at source in the event of an outbreak.

The Ministries responsible for Livestock Development and Health have been controlling previous outbreaks of RVF in isolation and in an ad hoc manner through Ministerial contingency plans. The preparation of the current NRVF-EPRP has therefore taken into consideration the desires of the previous ministerial plans. The NRVF EPRP measure takes into consideration the dynamics of RVF virus and environment, scientific and technological advances, improved surveillance procedures, change of national and international policies and legislations and stakeholder's interests (URT, 2010). The NRVF-EPRP preparation process followed the FAO/OIE/WHO and USAID guidelines. The preparedness plan is in line with the National Livestock Policy of 2006 and has been harmonized with the Regional RVF emergency preparedness and response plans such as those of East African Community (EAC), Southern Africa Development Community (SADC), African Union–Inter-African Bureau for Animal Resources (AU-IBAR) and Regional Indicative Strategic Development Plan (RISDP) (URT, 2010).

Suggestions have been put forward that higher specificity of forecast models will be needed to be confidently used to activate action steps which require commitment of limited public and animal health resources. The specificity may be increased by including animal surveillance to establish the degree of herd immunity and entomologic surveillance to identify potential for disease spread (Breiman *et al.,* 2010). Timely prevention and control of RVF epizootics will significantly reduce the scale of impacts of the disease on lives, livelihoods and local national and regional economies. Close collaboration between veterinary services and public health sectors are essential for the effective prevention and control of RVF and other zoonoses. Since its first detection, there has been little achievement on development of effective livestock vaccine with long shelf-life to conform to the episodic nature of RVF. The existing livestock vaccine (Smithburn, 1949) has a shelf–life of around 4 years, while the interval between outbreaks tends to be around 10 years or even 20 years during some inter-epidemic periods. Because of limited resources the veterinary authorities become reluctant to maintain vaccine stocks for RVF which are likely to expire before they are used. Manufacturers also avoid maintaining large stocks, which are likely to reach expiry dates before they can be sold. To overcome this problem, new and improved vaccines that have longer shelf-lives are required or more accurate earlier warning systems should be developed to provide manufacturers with the lead time required to produce vaccines prior to outbreaks (Geering & Davies, 2002).

Challenges and opportunities

Since its first detection, there have been about six outbreaks in Tanzania. However, the 2007 epidemic was the most severe and underlined the need for collaboration among different actors, institutions and countries in controlling the spread of the outbreak. Evidence shows that control measures that were taken in Tanzania and Kenya mirrored the multidimensional nature of RVF. It included closing livestock

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markets and butcheries, imposing movement controls and quarantines, and providing advice warning against drinking raw milk, slaughtering animals, or eating uninspected meat. Collaboration is not only confined to outbreak control but also in the strengthening of outbreak preparedness (ILRI/FAO, 2009; Jost *et al.,* 2010). The tool is based upon the identification of key decision points in the progression of events leading up to an outbreak, and allows investment in mitigations to be balanced against the escalating level of risk of an outbreak. The concept is that a phased response minimizes the risk of incorrect decisions and maximizes preparedness in the event of an outbreak (Clements *et al.,* 2007). The initial step for RVF control is a ban on raw milk, home slaughter, animal quarantine and placing community health workers armed with health messages at points of congregation of high risk individuals such as watering holes for livestock and market places. Response and mitigation should focus on; (i) Initiation of enhanced surveillance activities; (ii) Imposition of animal movement restrictions/ quarantines; (iii) Mosquito control programmes including distribution of mosquito nets and livestock dipping with insecticides; (iv) Dissemination of public information to mobilize social and cultural activities directed at reducing human contact; and (v) Implementation of at risk livestock vaccination (Amwanyi *et al.,* 2010).

Many of the RVF epizootics/ epidemics have affected pastoral and agro-pastoral livestock and people themselves. Pastoralists and agro-pastoralists are the people who live below the poverty line; therefore, when RVF outbreaks occur they are normally unable to report the outbreak to the veterinary office or medical facilities due to remoteness and lack of communication facilities. The major risk factors associated with human cases in nomadic pastoral and agro-pastoral communities are contact with sick animals and animal products including blood, meat and milk. High precipitation associated with flooding in an area of high density of livestock create conducive environment for RVF outbreak. The life style of nomadic pastoralists and agro-pastoralists is also one of the risk factors for contracting the infection. The episodic nature of the disease creates special challenges for its mitigation and control and many of the epidemics happen when the governments and communities at risk are not prepared and have limited resource to contain the disease at source. Inadequate maintenance of standard bio-security practices in livestock production and lack of proper Personal Protective Equipment (PPE) predisposes animal workers and medical personnel to contracting the infection during routine professional practices. In general, the surveillance systems for early detection and response for RVF in both humans and animals are inadequately operational due to limited funds.

The countries at risk have a number of challenges to address for the prevention and control of RVF such as:- (i) Surveillance systems for early detection and response for RVF in both humans and animals are not adequately operational due to limited funds; (ii) Inadequate maintenance of standard bio-security practices in livestock production enhancing disease introduction and spread; (iii) Inadequate management of livestock and livestock products movement; (iv) Inadequate marketing systems for livestock and livestock products; and (v) Low public awareness in prevention and control of RVF.

Since independence, there has been a great advancement in terms of increased trained human resource both for public health and veterinary services. With availability of transport facilities and all weather road networks it is possible to reach the remotest area in Tanzania within 72 hours. However, lack of adequate mobile laboratory equipment and enough PPE for all trained personnel affects the ability to mobilise several teams to make a quick diagnosis and take necessary mitigation measures to contain the disease at source. Seeking Meteorological information from NASA, FAO/EMPRES, IGAD, GEIS, CPAC, RSSD and other regional and national meteorological centres is an opportunity for getting early warning for possible RVF outbreak.

Conclusion

Despite technological advancement and knowledge on the epidemiology of RVF and presence of enough trained manpower, 50 years after independence Tanzania like many at risk African countries is not well prepared to contain the disease at source in the event of an outbreak. Preparation of NRVF-EPRP is a sign of commitment for the lead Ministries with support from international organisations

(WHO, FAO, USAID, AU-IBAR). However, due to poor economy it is difficult to set aside financial resource waiting for 5-20 years for a possible outbreak to occur while there are other pressing issues in the communities. On the other hand there has been laxity in taking expert advice from professionals by policy makers especially on the proper control of livestock movement which is the primary source of the disease epidemic to at risk human population.

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References

Amwanyi, A.S., Gould, H.L., Sharif, S.K., Nguku, P.M., Omolo, J.O., Mutonga, D., Rao, C.Y., Lenderman, E.R., Schnabel, D., Paweska, J.T., Katz, M., Hightower, A., Kariuki Njenga, M., Feikin, D.R., & Breiman, R.F. (2010) Risk Factors for Severe Rift Valley fever infection in Kenya, 2007. *American Journal of Tropical Medicine and Hygiene* 83 (Suppl 2), 14-21.

Anyamba, A., Linthicum, K.J., Small, J., Britch, S.C., Pak, E., de la Rocque, S., Formenty, P., Hightower, A.W., Breiman, R.F., Chretien, J.P., Tucker, C.J., Schnabel, D., Sang, R., Haagsma, K., Latham, M., Lewandowski, H.B., Magdi, S.O., Mohammed, A.M., Nguku, P.M., Reynes, J.M., & Swanepoel, R. (2010) Prediction, assessment of the rift valley fever activity in East and Southern Africa 2006-2008 and possible vector control strategies. *American Journal of Tropical Medicine and Hygiene* 83 (Suppl 2), 43-51.

Arborio, M., & Hall, W.C. (1989) Diagnosis of a human case of Rift Valley fever by immunoperoxidase demonstration of antigen in fixed liver tissue. *Research in Virology* 140, 165-168.

Balkhy, H.H., & Memish, Z.A. (2003) Rift Valley fever: an uninvited zoonosis in the Arabian Penninsula. *International Journal of Antimicrobial Agents* 21, 153-157.

Breiman, R.F., Minjauw, B., Sharif, S.K., Ithondeka, P., & Kariuki Njenga, M. (2010) Rift Valley Fever: Scientific pathways toward public health prevention and response. *American Journal of Tropical Medicine and Hygiene* 83 (Suppl 2), 1-4.

Clements, A.C., Pfeiffer, D.U. & Martin, V. (2007) A Rift Valley fever atlas for Africa. *Preventive Veterinary Medicine* 82, 72-82.

Coetzer, J.A. (1982) The pathology of Rift Valley fever. II: Lesions occurring in field cases in adult cattle, calves and aborted foetuses. *Onderstepoort Journal of Veterinary Research* 49, 11-17.

Daubney, R., Hudson, J.R. & Garnham, P.C. (1931) Enzootic hepatitis or Rift Valley fever: an undescribed virus diease of sheep, cattle, and man from East Africa. *Journal of Pathology and Bacteriology* 34, 545-579.

Davies, F.G., & Martin, V. (2003) Recognizing Rift Valley Fever. Rome, Italy: Food and Agriculture Organization of the United Nations. http://www.fao.org/DOCREP/006/Y4611E00.HTM (Accessed on 13th June 2011).

Evans, A., Gakuya, F., Paweska, J.T., Rostal, M., Akoolo, L., Van Vure, P.J., Manyibe, T., Macharia, J.M., Ksiszek, T.G., Feikin, D.R., Breiman, R.F., & Kariuki Njenga, M. (2008) Prevalence of antibodies against Rift Valley Fever Virus in Kenyan wildlife. *Epidemiology and Infection* 136, 1261-1269.

FAO (1999) New technologies in the fight against transboundary animal diseases. *Animal Production and Health,* 144, 118.

Flick, R., & Bouloy, M. (2005) Rift Valley fever virus. *Current Molecular Medicines* 5, 827-834.

Frank, S.A., & Feffrey, J.S. (2001) The probability of severe disease in zoonotic and commensal infections. *Proceedings of Biology and Science* 268, 53-60.

Fyumagwa, R.D., Runyoro, V., Horak, I.G., & Hoare, R. (2007) Ecology and control of ticks as disease vectors in wildlife of the Ngorongoro Crater, Tanzania. *South African Journal of Wildlife Research* 37, 79-90.

Fyumagwa, R.D., Simmler, P., Meli, M.L., Hoare, R., Hofmann-Lehmann, R. & Lutz, H. (2011) Molecular detection of *Anaplasma, Babesia* and *Theileria* species in a diversity of tick species from Ngorongoro Crater, Tanzania. *South African Journal of Wildlife Research* 41, 79-86.

Geering, W.A., & Davies, F.G. (2002) Preparation of RVF Contigency plans. FAO Animal Health Manual No. 15. Rome, Italy: Food and Agriculture Organization of the United Nations. http://www.fao.org/DOCREP/005/Y4140E/Y4140E00.HTM (Accessed on 13th June 2011).

Grace, D., Jost, C., Macgregor-Skinner, G. & Mariner, J.C. (2008) Participation of small farmers in animal health programmes. Presented at the Office International des Epizooties 76th General Session, 25-30 May 2008, Paris France.

Harper, T.K. (2004) Rift Valley Fever. http://www.tarakharper.com/v_rift.htm. (Accessed on 13th June 2011).

ILRI (2008) Decision-support tool for prevention and control of Rift Valley fever epizootics in the Greater Horn of Africa. Draft Report.

ILRI/FAO (2009) Decision support tool for prevention and control of rift valley fever epizootics in the Greater Horn of Africa. Version1. ILRI Manuals and Guides No 7. Nairobi, Kenya: ILRI and Rome, Italy: FAO. International Livestock Research Institute/Food and Agriculture Organisation of the United Nations.

Jost, C.C., Nzietchueng, S., Kihu, S., Bett, B., Njogu, G., Swai, E.S. & Mariner, J.C. (2010) Epidemiological assessment of the Rift Valley fever outbreak in Kenya and Tanzania in 2006 and 2007. *American Journal of Tropical Medicine and Hygiene* 83 (Suppl 2), 65-72.

Jup, P.G., Kemp, A., Grobbelaar, A., Lema, P., Burt, F.J., Alahmed, A.M., Al Mujalli, D., Al Khamees M. & Swanepoel, R. (2002) The 2000 epidemic of Rift Valley fever in Saudi Arabia: mosquito vector studies. *Medical and Veterinary Entomology* 16, 245-252.

Linthicum, K.J., Anyamba, A., Tucker, C.J., Kelley, P.W., Myers, M.F., Peters, C.J. (1999) Climate and satellite indicators to forecast Rift Valley fever epidemics in Kenya. *Science* 285,397-400.

MLDF (2008) Ministry of Livestock Development and Fisheries. *Annual Report 2007, Department of Veterinary Services, Tanzania.*

Mariner, J.C. & Paskin, R. (2000) Manual on participatory epidemiology.Methods for the collection of action-oriented epidemiological intelligence. *Food and Agriculture Organisation of the United Nations (FAO) Animal Health Manual No. 10 Rome, Italy.*

Mohammed, M., Mosha, F., Mghamba, J., Zaki, S.R., Shieh, W-J., Paweska, J., Omolo, S., Gikundi, S., Mmbuji, P., Bloland, P., Zeidner, N., Kalinga, R., Breiman, R.F.,& Njenga, M.K. (2010) Epidemiological and clinical aspects of a Rify Valley fever outbreak in humans in Tanzania, 2007. *American Journal of Tropical Medicine and Hygiene* 83 (Suppl 2), 22-27.

Munyua, P., Murithi, R.M., Wainwright, S., Githinji, J., Hightower, A., Mutonga, D., Macharia, J.M., Ithondeka, P.M., Mussa, J., Breiman, R.F., Bloland, P., Njenga, K.M. 2010. Rift Valley fever outbreak in livestock. *American Journal of Tropical Medicine and Hygiene* 83 (Suppl 2), 58-64.

NASA (2002) Rift valley fever.http:science.nasa.gov/headlines/y2002/17apr.rvf.htm. (Accessed on 13th June 2011)

Nguku, P., Sharif, S.K., Mutonga, D., Anyangu, S.A., Omolo, J., Mohammed, O., Farnon, E.C., Gould, L.H., Lederman, E., Rao, C., Sang, R., Schnabel, D., Feikin, D.R., Hightower, A., Njenga, M.K., Breiman, R.F. (2010) An investigation of a major outbreak of Rift Valley fever in Kenya: 2006-2007. *American Journal of Tropical Medicine and Hygiene* 83 (Suppl 2), 5-13.

Paweska, J.T., Burt, F.J., & Swanepoel, R. (2005) Validation of IgG sandwich and IgM –capture ELISA for detection of antibody to Rift Valley fever virus in humans. *Journal of Virology and Methods* 124, 173-181.

Sang, R., Kioko, E., Lutomiah, J., Warigia, M., Ochieng, C., O'Guinn, M., Lee, J.S., Koka, H., Godsey, M., Hoel, D., Hanafi, H., Miller, B., Schnabel, D., Breiman, R.F., & Richardson, J. (2010) Rift Valley

DOI: http://dx.doi.org/10.4314/thrb.v13i5.3

fever virus epidemic in Kenya, 2006/ 2007: the entomological investigations. *American Journal of Tropical Medicine and Hygiene* 83 (Suppl 2), 28-37.

Shieh, W-J., Paddock, C.D., Lederman, E., Rao, C.Y., Gould, H.L., Mohammed, M., Mosha, F., Mghamba, J., Bloland, P., Njenga, M.K., Mutonga, D., Amwanyi, A.S., Guarner, J., Breiman, R.F., & Zaki, S.R. (2010) Pathologic studies on suspect animal and human cases of Rift Valley fever from outbreak in Eastern Africa, 2006-2007. *American Journal of Tropical Medicine and Hygiene* 83 (Suppl 2), 38-42.

Smithburn, K.C. (1949). Rift Valley fever: the neurotropic adaptation of the virus and the experimental use of this modified virus as a vaccine. *British Journal of Experimental Pathology* 30, 1-16.\

Shoemaker, T., Boulianne, C., Vincent, M.J., Pezzanite, L., Al-Qahtanii, M.M., Al-Mazrou, Y., Khan, A.S., Rollin, P.E., Swanepoel, R., Ksiazek, T.G. & Nichol, S.T. (2002) Genetic analysis of viruses associated with emergence of Rift Valley Fever in Saudi Arabia and Yemen, 2000-01(Research). *Emerging Infectious Diseases* 8, 1415-1420.

URT (2010) National Rift Valley Fever Emergency Preparedness and Response Plan. Dar es Salaam, Prime Minister's Office.

Van der Lugt, J.J., Coetzer, J.A. & Smit, M.M. (1996) Distribution of viral antigen in tissues of new-born lambs infected with Rift Valley fever virus. *Onderstepoort Journal of Veterinary Research* 63, 341-347.

WHO (2007) Rift Valley Fever an Overview. Fact sheet No. 207, Revised September 2007.

Woods, C.W., Karpati, A.M., Grein, T., McCarthy, N., Gaturuku, P., Muchiri, E., Dunster, L., Hunderson, A., Khan, A.S., Swanepoel, R., Bonmarin, I., Martin, L., Mann, P., Smoak, B.L., Ryan, M., Ksiazek, T.G., Arthur, R.R., Ndikuyeze, A., Agata, N.N., & Peters, C.J. (2002) An outbreak of Rift Valley fever in northeastern Kenya, 1997-1998. *Emerging Infectious Diseases* 8, 138-144.