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COMMENTARY

The case for a 'one health' approach to combating vector-borne diseases

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Vector-borne diseases (VBDs) account for 17% of the estimated global burden of all infectious diseases, and transmission has become increasingly ubiquitous with the largest risk zones in Africa, Asia, and the Americas. As a major cause of morbidity and mortality in humans and livestock in pastoral and mixed farming communities in developing countries, VBDs reinforce the vicious cycle of poverty by limiting productivity and the ability to produce food or earn income to purchase food or medical services. Due to the influence of human activity on disease incidence and the direct and indirect impact on human health and livelihoods, VBDs are highly suited to 'one health' concept for combating infectious diseases. Increased human mobility, population growth, trade, and climate change constitute major risk factors for geographic expansion to new areas. Sub-Saharan Africa, which accounts for a significant share of the global disease burden, has an annual population growth rate of about 2.6%, above the current world average of 1.2% (1). High population growth rate coupled with expanding mining and logging operations in pristine forests influence human settlement patterns and accelerate deforestation. This causes ecological disequilibrium, resulting in loss of biodiversity and increased host–vector contact rate. Most apparently, vector-borne pathogens could spill over more readily within a disrupted ecosystem than within an intact, diverse ecosystem. Additionally, deforestation will cause drier conditions that will have an impact on the dynamics of infectious diseases, especially those associated with forest vectors and reservoirs, such as malaria, leishmaniasis, and arboviral infections (2, 3). Climate change will engender both short- and long-term impacts on vector-borne pathogen transmission. It is estimated that average global temperatures will rise by 1.0–3.5°C by 2100 (4), increasing the likelihood of many VBDs. For example, the increase in annual temperature and precipitation in East Africa has been particularly associated with the outbreak of Rift Valley fever (RVF) in Kenya (5). Thus, ecological disruptions could cause both temporal and spatial shifts in temperature, precipitation, and humidity that could affect the ecology of vectors, consequently increasing the risk of pathogen transmission to humans and livestock.

On a high note, however, significant strides have been made in the fight against several major VBDs. In the last five decades in sub-Saharan Africa, malaria and human African trypanosomosis (caused by *Trypanosoma brucei gambiense* and *Trypanosoma brucei rhodesiense*) transmissions have declined significantly. The expansion and scale-up of malaria prevention and treatment interventions in 2000–2012 saved approximately 3.3 million lives globally and malaria death rates in Africa were cut in half (6). Meanwhile, the number of new cases of human sleeping sickness, mainly in rural mixed farming and pastoral communities, in the 36 African countries affected, has reportedly dropped significantly, below 10,000 for the first time in 50 years and with only about 7,000 recorded cases in 2012 (7). Although these accomplishments are highly commendable, it should be noted that they were achieved on a platform of decades of sustained international partnerships, and financial and material support from major multilateral organizations and donor institutions.

Although there is ample reason for cautious optimism, the fight against VBDs is far from over. For example, African animal trypanosomosis (caused by *Trypanosoma congolense*, *Trypanosoma vivax*, or *T. brucei*) is still highly prevalent in most of sub-Saharan Africa, where it remains, arguably, the most important VBD limiting livestock production and productivity (8–10) causing immeasurable impact on poverty, food, and nutritional security. Direct losses due to this disease are estimated at US$1–1.2 billion per year, and in terms of agricultural Gross Domestic Product,

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US$4.75 billion per year (11). Meanwhile, heartwater disease caused by *Ehrlichia ruminantium*, a rickettsial pathogen, is considered a major threat to food and nutritional security as it constrains livestock improvement programs in sub-Saharan Africa and on some islands in the Caribbean (12). The presence of experimental vectors, *Amblyomma cajennense*, *Amblyomma maculatum*, and *Amblyomma dissimile*, in mainland United States [reviewed in (12)] suggests that the disease could become established, with devastating economic consequences, once introduced into the ruminant livestock population. There is no vaccine for use in the US and no reliable or safe one for use globally. African swine fever virus, maintained and transmitted by soft ticks, *Ornithodoros* spp., is causing serious economic losses to the US$150 billion global pig industry. First reported in East and southern Africa, the disease spread to central and West Africa and to the Indian Ocean islands of Madagascar and Mauritius (13, 14). In 2007, further spread of ASF occurred with the introduction of the virus to Georgia in the Caucasus followed by widespread distribution to parts of Russia and neighboring countries of the former Soviet Union, Armenia, and Azerbaidjan (15). Given the history of ASF in the Caribbean (Cuba, Dominican Republic, and Haiti) and South America (Brazil) (15, 16), there is profound risk of introduction and subsequent establishment of ASF in North America, where four of the five *Ornithodoros* species experimentally infected with ASF are found: *O. coriaceus*, *O. turicata*, *O. parkeri* and *O. puertoricensis* (17). Attempts to produce a protective vaccine have so far not yielded concrete results. In sub-Saharan Africa, vector-borne pathogens such as Rift Valley fever virus (RVFV; mosquito-borne), *Borrelia* spirochetes causing tick-borne relapsing fever, and *Rickettsia africae* causing African-tick bite fever are increasingly implicated in the incidence of acute febrile illness in pastoral and mixed farming communities across the continent (18–22). These zoonotic pathogens occur throughout sub-Saharan Africa and affect the impoverished more severely thus worsening the vicious cycle of poverty and food insecurity. They are often times misdiagnosed as clinical malaria causing chronic complications and long-lasting public health impact (23, 24). Consequently, if neglected tropical diseases (NTDs) are defined as a group of infectious tropical diseases in developing countries that are both *poverty-promoting* and *long-lasting* in their health impact (25), then consideration should be given to adding these diseases to the list of NTDs. And in South America, where more than 70% of the population live in urban towns and cities, increasing urbanization and the *Aedes aegypti* mosquito population will worsen the number of dengue cases. In fact, over the past decade (2003–2013), the number of dengue cases has reportedly increased fivefold and has become a leading cause of illness and death in the tropics and subtropics (26). Although the incidence of dengue in Africa (notably West Africa) appears to be grossly underreported, the disease is gaining increasing recognition as one of the major causes of acute febrile illness in local communities (27). High population densities, increasing urbanization, and abundant vector population constitute major risk factors.

A paradigm shift to one health concept is necessary to win the global fight and prevent the emergence and spread of VBDs to new areas. A glaring example is the significant spread and establishment of vector-borne zoonotic diseases worldwide such as West Nile Virus (WNV), Crimean-Congo hemorrhagic fever (CCHF), and Japanese encephalitis (28). CCHF, transmitted largely by ticks, has spread to more than 30 countries in a range of ecological conditions (28). Japanese encephalitis unexpectedly emerged in Australia, highly distant from the previous known outbreak in Indonesia (28). Of great significance, the widespread establishment of WNV demonstrates the vulnerability of non-endemic countries to the introduction of arboviruses; and RVFV, similar to WNV, transmitted by a range of mosquito vector species and other arthropods, many of which are currently present in North America and Europe (29–32), presents credible risk. The recent discovery of heartland virus (a *Phlebovirus* detected predominantly in *Amblyomma americanum* ticks), which is a close relative of the Chinese severe fever with thrombocytopenia syndrome virus, in patients with history of tick bite in the US (33–36); and the latest outbreak of arboviral pathogens, bluetongue virus, and schmallenberg virus, transmitted by *Culicoides* biting midges, in ruminants in Europe (37), seems to portray a disturbing trend in the emergence of new disease threats associated with vector-borne pathogens that impact humans and livestock.

The connectedness and interdependence of animal and human health demand full embrace of one health concept as a strategy to prevent the emergence and global spread of vector-borne pathogens. Any sustainable approach must include building relevant capacity, both human and technical, and implementing intervention programs at the sources of potential infection and epidemics. At present, these foci have emerged predominantly in developing countries in Africa, Asia, and South America. To profound dismay, and despite remarkable strides and achievements in the biomedical research field in the past decades, we have not succeeded in developing safe and reliable vaccines against a number of VBDs including malaria, dengue, and RVF, whereas vaccines and diagnostics for a number of zoonotic and economically important livestock diseases prevalent in developing countries remain either unavailable or inaccessible to significant proportions of resource-poor livestock farmers. Combating VBDs on a global scale is a challenging endeavor that will require foremost,

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enhanced collaborative surveillance involving both medical and veterinary personnel, as well as sustained investments in research and development, most particularly in rapid pathogen detection and vaccine technologies. This strategy resonates with the stipulations highlighted in the United Nations Millennium Development Goals, which ranked molecular diagnostics and vaccines highest in the top 10 biotechnologies for improving health in developing countries (38). Consequently, achieving success will require radically more international and sustained commitment – in financial, material, logistical, and expert support to research and development than has been offered so far.

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