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Public health importance of mosquito-borne diseases in the Seychelles (Indian Ocean)

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Abstract

This review examines the current situation of mosquito-borne diseases in Seychelles, encompassing all diseases which have been demonstrated in Seychelles (whether the vector is present or not) and selected diseases not demonstrated in Seychelles but for which the vector is locally present. For each considered disease, we estimated a potential risk for their emergence or re-emergence.

Sixteen different species of mosquitoes belonging to four families (*Aedes*, *Culex*, *Mansonia*, and *Uranotaenia*) have been identified in Seychelles and the most common are *Aedes albopictus* and *Culex pipiens fatigans*. Rare sporadic cases of dengue fever have been noticed during these last 19 years (after the last epidemic), all without haemorrhagic fever or shock syndrome. No new case of filariasis has occurred for the past 10 years. No clinically diagnosed cases were reported for West Nile, Sindbis or Chikungunya virus infections despite the fact that positive serology was found for each of them. The country is free of yellow fever, Japanese encephalitis, epidemic polyarthritis (Ross River virus), and Rift Valley fever. Annually, approximately ten cases of malaria are reported, all imported as Seychelles is free of mosquitoes of the *Anopheles* family. Among these agents, the greatest risk of future epidemics is from dengue viruses with a threat for haemorrhagic fever or shock syndrome.

Control of the local mosquito populations, prevention of importation of overseas mosquitoes, and isolation of suspected human cases from local mosquitoes are the basic principles to maintain the actual favourable but fragile situation in Seychelles.

Introduction

Mosquito-borne diseases are an important public health problem in most tropical countries. In Seychelles, a tropical country, cases of imported malaria, dengue fever, and filariasis have been diagnosed over the last decades.

Positive serology has been found in the population for dengue fever (1,2), West Nile fever (2), filariasis (3,4), Sindbis and Chikungunya virus infections (1). No clinical or serological evidence of disease has been reported for yellow fever, Japanese encephalitis, epidemic polyarthritis (Ross River virus) and Rift Valley fever.

Up to now, 16 different species of mosquitoes belonging to four families (*Aedes*, *Culex*, *Mansonia*, and *Uranotaenia*) have been identified in Seychelles and the most common are *Aedes (Ae.) albopictus* and *Culex (Cx.) pipiens fatigans* (Table 1) (5). These mosquitoes are known vectors for at least 21 diseases (6). In addition, other species of mosquitoes could be imported from other countries and at least 27 different viruses, one protozoan (*Plasmodium*), two nematodes (*Filaria* and *Dirofilaria*), and insect (Diptera) larvae (myiasis) have been reported to be transmitted by mosquitoes world-wide (6).

This review examines the current situation of mosquito-borne diseases in Seychelles as the frequency of these diseases mainly relates to vector population control and identification of infected cases. The review encompasses 1) all diseases which have been demonstrated in Seychelles (whether the vector is present or not); 2) selected diseases not demonstrated in Seychelles but for which the vector is locally present (Table 2). This selection was based on criteria involving the frequency of the disease, its severity and its potential for importation, particularly with regards to airline connections.

For each disease, we estimated a potential risk for their emergence or re-emergence in Seychelles (Table 3). Noticeably, the risk of occurrence in Seychelles of any mosquito-borne disease can never be null as introduction of new mosquitoes and/or infected patients can potentially always occur, particularly in view of increasing airline connections and population movements (7).

Table 1. Mosquitoes present in Seychelles (5) (1995) and related selected diseases

Mosquito	Proportion (%)	Disease (6)
<i>Aedes</i>		
<i>aegypti</i>	0.6	dengue fever*, yellow fever, Chikungunya*
<i>albopictus</i>	69.6	dengue fever*, yellow fever, Chikungunya*
<i>pembaensis</i>	<0.1	-
<i>vigilax</i>	<0.1	epidemic polyarthritis, filariasis (<i>Wuchereria</i>)*, Sindbis*
<i>albocephalus</i>	<0.1	-
<i>Culex</i>		
<i>pipiens fatigans</i>	18.7	filariasis (<i>Wuchereria</i>)*, West Nile fever*, Rift Valley fever
<i>scotii</i>	<0.1	-
<i>stellatus</i>	2.4	-
<i>simpsoni</i>	<0.1	-
<i>tritaeniorhyncus</i>	0.2	Japanese encephalitis, West Nile fever*, Sindbis*, Chikungunya*
<i>fuscocephallus</i>	2.2	Japanese encephalitis
<i>wigglesworthi</i>	<0.1	-
<i>Mansonia</i>		
<i>uniformis</i>	<0.1	filariasis (<i>Brugia</i>), Chikungunya*, Rift Valley fever
<i>Uranotaenia</i>		
<i>nepenthes</i>	-	-
<i>pandani</i>	6.3	-
<i>browni</i>	-	-

* Disease clinically and/or serologically demonstrated in Seychelles

Population, materials & methods

The archipelago of Seychelles consists of 115 islands (445 km²) situated in the Indian Ocean, 1800 km east of Kenya. According to a population census in 1994, the population consists of 74,331 inhabitants of which 90% live on the main island and 49% are aged less than 25 years. The climate is tropical, mostly equable; rainfall occurs throughout the year and averages 1,500 to 2,200 mm per year; temperature is stable between 24 and 31° Celsius; and humidity averages 75 to 82%. Commercial airlines connect Seychelles directly with Europe (UK, France, Germany, Italy, Russia, Switzerland), Africa (Dubai, Kenya, South Africa), Asia (India, Singapore), and insular countries of the Indian Ocean (Comoros, La Réunion, Madagascar, Mauritius). Medical care within a national health system is delivered free of charge and is easily accessible through community clinics, small cottage hospitals and a main referral hospital. The Environmental Health Section of the Ministry of Health manages the prevention of mosquito-borne disease in the country, including spraying the incoming planes, spraying the international airport, the port and their vicinity and spraying or inspecting ships coming from abroad.

Information on mosquito-borne diseases in Seychelles was collected from published reports and from non published data available locally.

Published reports

1. In 1968-69, entomological investigations were carried out over a period of 11 months in 14 islands of Seychelles (8). Thirteen species of mosquitoes were found. *Ae. albopictus*, *Cx. pipiens fatigans*, *Cx. simpsoni* and *Uranotaenia (Ur.) pandani* were the most widely distributed and the commonest. No

- Anophelini have been recorded. *Cx. pipiens fatigans*, the vector of bancroftian filariasis in Seychelles, has increased rapidly over the last decade. The house-index for all mosquitoes was relatively low everywhere.
2. In 1977, a dengue-like epidemic was investigated (2). Approximately 75% of the population had suffered from the disease. The estimated case-fatality rate was about 28/100,000 and deaths were attributed to encephalitic and meningitic complications. Dengue virus type 2 was identified by isolation (in patients and mosquitoes) and serologic tests. 133 sera were obtained several months after the epidemic from people not randomly chosen and aged between 6 and 72 years. Among these 133 sera, 100 reacted by neutralisation test (plaque-reduction method) with dengue 2 antigen, 31 for yellow fever (which was attributed to serological cross-reaction to dengue 2 antigen and post vaccination status against yellow fever) and 18 for West Nile (which was attributed to serological cross-reaction to dengue 2 antigen). *Ae. albopictus* was the probable vector of this dengue 2 virus epidemic.
3. In 1979, a serological survey was carried out following a new epidemic in December 1978 and January 1979 with a clinical presentation similar to that seen during the epidemic of 1977 (1). Sera were collected from 231 outpatients at the Victoria General Hospital, aged 11 to >60 years and of equal sex distribution. At the time of blood collection, none of the patients had symptoms compatible with a diagnosis of dengue fever. Neutralisation test by plaque reduction method showed antibody to dengue 1, 2, 3, and 4 viruses in respectively 92.1%, 98.7%, 82.1% and 81.7%. The authors mentioned that dengue 2 type was identified around this period in visitors to Seychelles and in La

Table 2. Characteristics of selected mosquito-borne diseases relevant for Seychelles (1998)

Disease	Agent (family)	"Incubation period" infective for vector (days)	Vector	Reservoir	Case-fatality rate from the literature (%) (Reference)	Disease in Seychelles	Seroprevalence in Seychelles (%) (year) (Reference)
Dengue fever	dengue virus 1-4 (Flaviviridae)	2-7	<i>Aedes</i> *	none	0-20 (18)	last epidemic in 1979, possible sporadic cases after 1979	38-50 (1995)† 6.5 (1997) (10)
West Nile fever	West Nile virus (Flaviviridae)	1-7	<i>Culex</i> *, <i>Aedes</i> , <i>Anopheles</i> ,	birds**	0-5 (35)	clinically unrecognised	39 (1997) (10)
Filariasis	<i>Wuchereria bancrofti</i>	180-360	<i>Aedes</i> *, <i>Culex</i> *, <i>Anopheles</i>	none	0 but long term disability	no new clinical cases for the last 10 years	17 (1979) (4)
	<i>Brugia malayi</i>	180-360	<i>Mansonia</i> *, <i>Aedes</i> , <i>Anopheles</i>	none	0 but long term disability	no	unknown
Sindbis disease	Sindbis virus (Togaviridae)	2-7	<i>Culex</i> *, <i>Aedes</i> *	birds**	0 (49,50)	clinically unrecognised	7.4 (1979), (1) 0 (1997), (10)
Chikungunya disease	Chikungunya virus (Togaviridae)	2-3	<i>Aedes</i> *, <i>Culex</i> *, <i>Mansonia</i> *	non human primates	0 (49,50)	clinically unrecognised	8.7 (1979), (1) 0 (1997), (10)
Yellow fever	yellow fever virus (Flaviviridae)	2-14	<i>Aedes</i> *, <i>Haemagogus</i> , <i>Sabethes</i>	non human primates	19-50 (53)	no	23‡ (1978) (2)
Japanese encephalitis	Japanese encephalitis virus (Flaviviridae)	4-15	<i>Culex</i> *, <i>Aedes</i> , <i>Anopheles</i>	birds**, pigs**	10-40 (57)	no	unknown
Epidemic polyarthritis	Ross River virus (Togaviridae)	7-11	<i>Aedes</i> *, <i>Culex</i>	unknown	0 (6)	no	<0.1? (1979) (1)
Rift Valley fever	Rift Valley virus (Bunyaviridae)	2-7	<i>Culex</i> *, <i>Aedes</i> , <i>Anopheles</i> , <i>Eretmapodites</i> , <i>Mansonia</i> *, <i>Coquilletidia</i>	cattle**, goats**, sheep	<1-14 (65,66)	no	unknown
Malaria	<i>Plasmodium</i>	0	<i>Anopheles</i>	none	1 (69)	8-12 cases/year	unknown

* species able to transmit the disease exist(s) in Seychelles, ** present in Seychelles, † unpublished data, ‡ due to cross-reactive antibody and/or vaccination

Reunion. Positive serology by the same method was also found for West Nile (3.1%), Chikungunya (8.7%), and Sindbis (7.4%) viruses. Almost all sera reactive to Chikungunya and Sindbis had monotypic antibodies (no cross-reaction). One serum also reacted with Ross River virus but the titre was very low.

4. In 1979, a serologic survey was carried out to assess the current status of filariasis in Seychelles (4). Serum samples were collected from 417 native people randomly chosen among the outpatients of the Victoria General Hospital. Participants came equally from both genders and age classes. Positive serology was found in 17% and prevalence did not change substantially with age.
5. A survey on mosquito larval density was conducted in 1995 on the main island (Mahé) (5,9). High mosquito density was found with *Ae. albopictus*, *Cx. pipiens fatigans* and *Ur. pandani* being the most frequent. The author mentions that the population of *Ae. aegypti* has decreased and that of *Ae. albopictus* has almost doubled compared to a previous survey in the late 1960s. Two mosquitoes were identified for the first time: *Cx. tritaeniorhynchus* and *Cx. fuscocephallus*.
6. Following an outbreak of flu-like infections in December 1996 to February 1997 and numerous cases with fever and sore-throat in March-April 1997, a serological survey was done from May to August 1997 to assess the activity of dengue and other viruses (10). Analyses were conducted on a single serum sample collected from each of 490 non randomly selected patients; consisting of those attending health centres because of fever, healthy students, and volunteers from the Ministry of Health. There were 253 females and 237 males and age ranged from two to 94 years. Serum samples were examined at the Pasteur Institute, Antananarivo, Madagascar by ELISA for IgG and IgM antibodies against dengue 1 and 2, West Nile, Sindbis, Chikungunya, and Wesselsbron viruses. All enrolled individuals tested negative for IgM antibody and 6.5% tested positive for IgG against dengue 1 and/or 2 viruses. All individuals born after the last dengue outbreak (1978-79) had a negative test for IgG antibodies against dengue 2 virus, but two of them born after the epidemic (15 and 18-year old teenagers) tested positive for dengue 1 virus. West Nile IgG antibodies were found in 39% of tested sera and their prevalence increased with age. No antibodies against the other investigated viruses were found.

Unpublished data

Dengue antibody was determined on sera collected in 1995 as part of a survey on leptospirosis (11). Early and late sera were available in 123 consecutive patients admitted over a period of one year to the main hospital with symptoms compatible with acute leptospirosis and in 136 healthy persons randomly selected from the whole population, matched to cases for age, sex, and occupation. Among them, 84% were

males and age ranged from 7 to 76 years, but only 4.8% were born after the last epidemic of dengue in 1978-79. All sera were examined by ELISA for IgG and IgM antibodies against dengue viruses at Pasteur Institute, Noumea, New Caledonia. No IgM antibodies were detected. IgG antibodies were found in 50.4% of patients and 38.2% of healthy controls. Two subjects born after the last epidemic (1978-79) of dengue fever (aged 9 and 14) had positive IgG antibodies.

The risk of introduction in Seychelles of the considered agents was estimated taking into account: a) the presence or not of maritime and/or airline connections with countries where the disease is present, b) the importance of the population movement between these countries and Seychelles, c) the susceptibility of the travellers entering Seychelles to have contracted the disease in these countries (e.g., vaccinated vs not vaccinated, workers vs tourists, residing in urban vs rural areas), d) the prevalence of the disease in these countries, e) the incubation period of the disease, or the period of possible transmission of the agent to vector before onset of symptom in patient.

The risk of epidemic in Seychelles was estimated taking into account: a) the risk of introduction of the agent, b) the presence and frequency of the vector and reservoir(s) in Seychelles, c) the current immunity state of the population to the considered agent.

The public health importance of an epidemic was estimated taking into account: a) the immunity state of the population, and consequently the number of people who would be infected, b) the severity of the disease (case-fatality, disability).

Dengue fever

Dengue type 1-4 viruses (family Flaviviridae) are widely distributed in the tropical and subtropical countries and are transmitted by day-biting mosquitoes of the genus *Aedes*. Dengue fever is endemic on all continents and affects tens of millions of persons annually (12). After an incubation period of 2 to 7 days, the infection in most children is clinically mild or inapparent but is overt in nearly all adults (13). It may present as a diphasic fever marked by severe muscle and joint pain, photophobia and conjunctivitis followed by a morbilliform rash, and rarely results in death (14). Dengue virus infection occurring against a background of previous exposure to another serotype can result in haemorrhagic fever or shock syndrome (DHF/DSS). According to reports from Southeast Asia and Polynesia, DHF/DSS can occur in 10 to 25% of children with dengue infection (15,16), and with a case-fatality rate of 1-20% (17,18). The fact that, in these countries, DHF/DSS occurs more frequently in children reflects a high level of endemicity with a short time between successive epidemics: successive infections by new and different serotypes occurs mostly in children while adults, already immunised against at least two serotypes, experience mild clinical disease.

Table 3. Public health relevance of mosquito-borne diseases in Seychelles

Disease	Vector (0 to +++)	Reservoir (0 to +++)	Epidemics/ endemicity in the past 20 years (Y/N)	Sporadic cases in the past 2 years (Y/N)	Disease prevalence in countries with direct airline connections (0 to +++)	Risk of introduction of agent (0 to +++)	Risk of epidemics (0 to +++)	Public health importance of epidemics (0 to +++)	Main actions to prevent epidemics
Dengue fever + DHF/DSS	+++	0	Y	N	+++	+++	+++	+++	Reduce vector density, quarantine*
West Nile fever	++	++	Y	N	++	++	++	++	Reduce vector density, quarantine*
Filariasis	++	0	Y	N	++	+	+	++	Maintain socio-economic development, detect and treat human cases
Sindbis	+	++	Y	N	+	++	++	+	Quarantine*
Chikungunya	+++	0	Y	N	+	+	++	+	Reduce vector density, quarantine*
Yellow fever	+++	0	N	N	+	+	+	++++	Reduce vector density, quarantine*, vaccination
Japanese encephalitis	+	+++	N	N	+	++	+	+++	Quarantine*, vaccination
Epidemic polyarthritis	+	?	N	N	0	+	+	+	Quarantine*
Rift Valley fever	++	+	N	N	++	+	+	+++	Avoid importation of infected cattle, goats
Malaria	0	0	N	Y	+++	++++	+	++++	Avoid vector introduction

For all diseases, susceptibility of the population would be high as no large epidemics occurred over the last 20 years and/or low seroprevalence was found recently
 * Quarantine: isolation of acute human cases from local mosquitoes

The induction of DHF/DSS depends on multiple factors, including: a) the presence of enhancing and non neutralising antibodies elicited by previous heterologous dengue infection or by maternal transplacental transfer in infants >9 months old; b) the sequence of infection: for example, serotype 1 followed by serotype 2 is particularly dangerous (15); c) the infecting serotype and strain, the Southeast Asian serotype 2 strains having more potential to cause DHF/DSS than others (19); d) the susceptibility to DHF/DSS is higher in infants and drops with aging (20); e) malnutrition seems protective (21); f) blacks are less often affected than Caucasians (data from the 1981 DHF/DSS epidemic in Cuba have suggested the existence in blacks of a resistance gene (22)).

In Seychelles, epidemics have been reported in 1900, 1906, 1915, 1926 (23,24), 1976-77 (2) and 1978-79 (1). No case of DHF/DSS was demonstrated during the two last epidemics and there is no information about DHF/DSS during the previous epidemics. No case of acute dengue infection was found in the 123 patients with leptospiriosis-like syndrome (a clinical presentation similar to dengue fever) during the survey of 1995. In the serological surveys of 1995 and 1997, which were not representative of the general population, overall seroprevalence of IgG antibody was respectively 44% and 6% (the 1997 survey included more young persons than the 1995 survey). Noticably, four subjects born after the last epidemic (1978-79) were found positive (IgG antibodies) in the two surveys. Overall, these findings indicate no evidence of recent acute disease; seroprevalence in the population is compatible with the previous epidemics but does not exclude infection contracted later; and low activity of dengue virus demonstrated by the four subjects born after the last epidemic who had positive serology.

The high prevalence of *Ae. albopictus* (Breteau index: 17-100%; house index: 14-53%) (5), the 19-year interval without epidemic and the large proportion of the population susceptible to infection (without anti-dengue antibodies) argues against the presence of an active endemic strain. In addition, the small size of the Seychelles population prevents epidemics originating from a local strain as the virus has no other reservoir than human. It is therefore likely that the next epidemic will originate from an infected patient, whether symptomatic or not, arriving to Seychelles from overseas and will affect a large proportion of the population.

According to observations reported mostly from Southeast Asian countries, DHF/DSS seems unlikely to occur in Seychellois children at the time of the next epidemic, since few children have the dengue antibodies that would induce DHF/DSS. Nevertheless, the recent outbreak of DHF in January-August 1997 in Santiago de Cuba took place after the last two epidemics of dengue fever 18 and 16 years ago (type 1 and type 2 respectively) (22,19). The 1997 outbreak resulted in 205 cases with DHF and 12 deaths out of 3,000 hospitalised persons and was caused by a dengue 2 virus of recent Southeast Asia origin. The youngest DHF patient was 17 years old. This outbreak

provides evidence that many adults may experience DHF and that DHF may occur at any interval after a primary dengue infection. Seychellois adults with evidence of past dengue infection are probably at risk for DHF/DSS during the next epidemic.

Although a vaccine against dengue infection may possibly be available in some years (25,26) and new prevention measures introduced with the use of "anti-sense" RNA to prevent dengue viral replication in mosquitoes (27), classical vector control by reducing the number of breeding sites remains the cornerstone for prevention of future epidemics. Noticably, *Ae. albopictus* and *aegypti* tend to breed in used containers, tires and other man-made objects which may accumulate water so that mosquito control around human settlements (elimination of these containers and elimination of mosquitoes) is particularly effective in reducing the entire vector population. Isolation of patients suspected to have contracted the disease overseas from local mosquitoes is imperative. As many tourists and workers come to Seychelles from neighbouring countries where many dengue fever cases are reported (e.g. Singapore, Malaysia, Philippines, India), the likelihood of future epidemics in Seychelles is substantial.

West Nile fever

West Nile virus (family Flaviviridae) is one of the most widely spread arboviruses in Africa and Asia. Infection of man is tangential from cycles involving wild birds, acting as a reservoir and disseminating the virus in very different countries (28,29). The vectors are mosquitoes of the genus *Culex*, and rarely *Aedes* and *Anopheles* (30,31). Affected people (mostly children, but epidemics can also affect persons of all ages) show fever, sore throat, lymphadenopathy and sometimes a morbilliform rash. Rarely the disease is complicated by a neurological infection (32-34) which can result in death. A first major outbreak of West Nile fever in Europe occurred in the city of Bucharest and in the lower Danube valley (Romania) in 1996; a good example of disease emergence. The epidemic comprised 350 cases of meningoencephalitis with 17 deaths, all of which were over 50 years old (35).

In Seychelles, antibodies against West Nile virus were detected by neutralisation test, respectively in 14% and 3% of outpatients tested in 1977 and 1979 (2,1). In one of these studies, the authors suggested that West-Nile titres reflected cross-reactivity rather than true West Nile infection as West Nile antibody titres were generally low and these antibodies were mostly found in patients who had antibodies against dengue 2 virus (2). In the other study, the authors mentioned that all cases positive for West Nile virus were also positive for dengue virus (1). In the seroepidemiologic survey done in 1997 (10), 39% (190/490) of the tested individuals were positive for West Nile antibodies and antibody prevalence increased with age, which is consistent with other reports (36). Among them, 13% (25/190) were also positive for dengue antibodies. The high proportion of subjects reacting to West Nile virus but not to dengue virus and the increasing seroprevalence with age in this survey strongly suggests actual past human

infection with West Nile virus in Seychelles. It can be speculated that the population has been infected through epidemic waves of West Nile infection (asymptomatic cases or mimicking flu-like disease) rather than through endemic transmission as no serum contained specific IgM. The virus could infect humans either from a local transmission cycle involving local birds or by infected migrating birds. In Seychelles, West Nile fever or encephalitis has so far never been reported, possibly because clinicians are not familiar with the disease, but West Nile infection should be considered in the differential diagnosis of acute encephalitis. As no human immunisation is currently available, mosquito population control and use of repellents are the only methods to prevent outbreaks.

Filariasis

Filariasis is the most widely distributed human filarial parasite throughout the tropics and subtropics and it affects an estimated 120 million persons world-wide (37). 73 million are due to *Wuchereria bancrofti* with the largest number in India (38). Filariasis is mostly a disease of the poor and can serve as an indicator of underdevelopment (38). Humans are the only definitive host for this parasite. Natural vectors for *W. bancrofti* are *Cx. pipiens* mosquitoes in urban settings and anopheline, aedean mosquitoes in rural areas. Mosquitoes of the genus *Mansonia* are accessory vectors. The common clinical manifestations of lymphatic filariasis are asymptomatic microfilaraemia, chyluria, lymphatic inflammation and obstruction culminating in hydrocele and elephantiasis.

Wuchereria bancrofti is the only filarial nematode identified in humans in Seychelles. Although mosquitoes of the genus *Mansonia* (the vector of *Brugia malayi*) are present in Seychelles, this parasite has never been reported in the country. In 1968, the overall level of infection of the population was found to be 3.6% (3). In 1979, the last survey on filariasis conducted in Seychelles, showed that 17% of the population had been exposed to *W. bancrofti* (4). During these last 10 years, no new clinical cases were diagnosed in Seychelles. Notably, old cases of filariasis probably do not present an infection threat as treatments eliminating microfilariae (albendazole, diethylcarbamazine, ivermectin) and killing adult worms (diethylcarbamazine) are effective so that treated persons interrupt the transmission cycle. Otherwise, survival of adult *W. bancrofti* in untreated patients is limited to 10 years (39). Despite persistence of the vectors, it is likely that country-wide improvement in hygiene, education, housing, and medical treatment contributed to the decline of the disease. Sustained socio-economic development may protect the country against re-emergence. Dog filariasis (*Dirofilaria immitis*) was reported in Seychelles in 1969 with *Ae. albopictus* as vector (40), but this nematode was never found in local people.

Sindbis virus infection

Sindbis virus (family Togaviridae) is transmitted among birds by *Culex*, *Aedes*, *Anopheles* and *Mansonia* mosquitoes. Human cases were reported from Europe (Pogosta disease in Finland, Ockelbo disease in Sweden,

Karelian fever in former Soviet Union (41,42)), Africa (43), Asia (44), and Australasia (45). The disease, which has an incubation period of less than one week, begins with low fever, a macular to vesicular rash lasting for about a week and arthralgia. The arthritis is multiarticular, migratory and incapacitating, with resolution of the acute phase within a few days. Persistence of arthralgia and occasionally arthritis is a major problem and may last for months or even years without causing deformity.

Evidence of human infection with Sindbis virus has been found in Seychelles in 1979. Among 231 outpatients tested on Mahé, neutralising antibodies to Sindbis virus were found in 17 (7.4%) individuals and were specific for this virus in 16 (1). Among the 490 persons tested in 1997, none was found positive for Sindbis virus. Negative findings in the most recent serosurvey suggests no recent activity of the virus. It would however be informative to carry out serology in patients with chronic arthritis of unclear origin.

Chikungunya virus infection

Chikungunya ("the thing causing bending up") virus (family Togaviridae) has primates as the reservoir. It is transmitted mostly by *Aedes* mosquitoes (46) but *Cx. tritaeniorhynchus* can be an additional vector in Southeast Asia. Similarly to yellow fever virus, the virus is maintained among non human primates living in Africa (sylvatic cycle) and is also readily transmitted among humans in urban areas (urban cycle). So far, 18 countries of Africa or Asia have reported the disease (6,47). After an incubation period of two to three days, there is a brusque onset of fever and arthralgia with chills, headache, photophobia, conjunctival injection, and abdominal pain. Migratory polyarthritis affects mainly the small joints and a rash may appear within two to three days of disease. Irregularly, the virus can cause haemorrhagic syndrome (48). Recovery may require weeks and some patients continue to suffer from joint pain and recurrent effusions for several years. The disease is generally not fatal (49,50).

Concurrently to Sindbis virus, evidence of human infection with Chikungunya virus has been found in Seychelles in 1979 (1). Among 231 outpatients tested on Mahé, neutralising antibodies to Chikungunya virus were found in 20 (8.7%) subjects and were specific for this virus in 19. Among the 490 persons tested in 1997, none was found positive for Chikungunya virus. Similarly to Sindbis virus, the risk for re-emergence of Chikungunya virus infection exists if infected mosquitoes or patients enter the country from South Africa, for example.

Yellow fever

A total of 18,735 yellow fever cases and 4,522 deaths were reported in 44 countries from Africa and South America from 1987 to 1991, which represents the greatest amount of yellow fever activity reported to the World Health Organisation (WHO) for any 5-year period since 1948 (51). Case-fatality rate ranges from 19 to 50% (52,53).

Yellow fever has never been reported in Seychelles. Positive serology was found in 23% of the sera collected in Seychelles in 1977-78 at the time of the first dengue

fever outbreak (2). The investigators attributed this finding to a consequence of past vaccination against yellow fever and cross-reaction with the dengue 2 antigen.

As *A. aegypti* is the classical vector and *A. albopictus* a serious potential vector (54,55) for yellow fever, an outbreak for this typical haemorrhagic fever could occur in Seychelles if a traveller contracts the disease overseas, travels to Seychelles before symptoms appear (period of incubation: 2-14 days), is bitten by local mosquitoes prior to diagnosis and effective quarantine. A highly effective and well tolerated live attenuated vaccine was introduced in 1937 and universally used since the 1960s. The WHO, the United Nations Children's Fund (UNICEF) and the World Bank have recommended that African countries at risk for yellow fever add the vaccine to the routine Expanded Programme on Immunisation and studies show that this would be highly cost-effective (56). Despite the fact that the vector is present in Seychelles and the population is not systematically immunised (immunisation of children was initiated in 1995), the risk of a yellow fever epidemic is low as few persons come from endemic areas and those that do must produce evidence of prior vaccination when disembarking in Seychelles. In addition, spraying aeroplanes should prevent introduction of infected vectors. Prevention measures rely on proper case identification and isolation from local mosquitoes, vector population control and mass immunisation of the population. The association of *Ae. albopictus* and *aegypti* with human settlements and its subsequent control strategy mentioned in the paragraph on dengue fever also applies for yellow fever.

Japanese encephalitis

Japanese encephalitis is the most important cause of viral encephalitis in Asia (mostly Far East but also India and Singapore). It causes 50,000 cases per year and it resulted, for example, 45,000 cases and 4,300 deaths in 1990 (57). Recently, Japanese encephalitis cases occurred in areas where it had not been recognised previously (Australia, Nepal, Papua New Guinea) (58-60). Mosquitoes of the genus *Culex* (mainly *Cx. tritaeniorhynchus*) are the main vectors of Japanese encephalitis. Avian vertebrates are natural hosts and infected pigs represent an additional amplification factor for the virus (61). Japanese encephalitis (incubation period, 4-15 days; case-fatality rate, 10-40%) does not always produce an encephalitis syndrome but can also cause lower motor neurone, cranial nerve, limb or urinary bladder paralysis alone and can therefore mimic acute poliomyelitis or Guillain-Barré syndrome (62,63).

As vectors (*Cx. tritaeniorhynchus* and *Cx. fuscocephallus*) and reservoirs (birds and pigs) are present in Seychelles, conditions for an outbreak of Japanese encephalitis would be met if the virus was introduced by a traveller or bird, or by imported pig from any of the 26 Asiatic countries and Australia where it is present. This environment stresses the need for physicians to maintain a high level of diagnostic suspicion for all patients with fever, neurological disorders and history of recent travel in an area endemic for Japanese encephalitis. Isolation of these patients from local mosquitoes is essential until diagnosis is ruled out.

The risk for a Japanese encephalitis outbreak in Seychelles exists because of a direct airline connection with Singapore where outbreaks are reported, but this risk is low in view of the low prevalence of the vectors in Seychelles, the low incidence of the disease in countries reporting the disease, and the fact that pigs are imported to Seychelles from South Africa, which is free of the disease. However, this risk could increase in view of development of airline connections with Asiatic countries. An inactivated mouse brain-derived Japanese encephalitis vaccine is recommended only for travellers at high risk of exposure because of frequent allergic reactions and anecdotal reports of acute disseminated encephalomyelitis.

Epidemic polyarthritis

Ross River virus (family Togaviridae) is the most common alphavirus in Australasia (64) and it causes epidemics of polyarthritis in thousands of persons in rural and suburban areas annually. The virus is transmitted by *Ae. vigilax* and no definitive vertebrate host has been identified. The incubation period lasts 7 to 11 days and the clinical presentation is similar to Sindbis virus infection, but with a sudden onset of illness. Subsequent chronic arthritis can handicap patients for several months. Although the vector exists in Seychelles, the only serosurvey investigating this virus (1) showed no evidence of Ross River virus infection among 231 outpatients (one serum reacted with very low titre). In view of the result of this single small study, of the very low prevalence of the vector and of the absence of direct flights with countries endemic for the disease, the risk for an epidemic in Seychelles seems small. Isolation from local mosquitoes of an infected traveller is the only advocated preventive measure.

Rift Valley fever

Rift Valley fever is a disease of domestic ruminants in Africa caused by a mosquito-borne virus (family Bunyaviridae) and characterised by abortions, necrotic hepatitis, and haemorrhagic syndrome. Humans become infected from contact with tissues of infected animals or by mosquito bite. Vectors are mosquitoes of the families *Aedes*, *Anopheles*, *Culex*, *Eretmapodites* and *Mansonia* and the reservoirs are domestic ruminants like cattle, goats, and sheep. Infected humans usually experience influenza-like illness; severe complications (haemorrhagic disease, encephalitis and ocular sequelae) may occur during epidemics and account for much of the mortality (<1-14%) (65,66). So far, the disease has been reported in 31 countries all situated in Africa. An outbreak in Kenya, Somalia, and Tanzania in 1997-1998 involved an estimated 89,000 humans (6). Vaccination is the only effective way to protect livestock (67). There is no validated vaccine for humans.

No data on Rift Valley fever are available for Seychelles. *Cx. pipiens fatigans* and *Cx. tritaeniorhynchus*, which transmit the disease, are present in Seychelles. Therefore there is a possibility of an epidemic if infected mosquitoes or cattle are introduced, for example by the existing airlines connections with Kenya, South Africa or Madagascar (where epidemics have occurred). This risk is however low as the disease occurs mostly in the countryside far from

the airports. In addition, a minimal risk of infection exists for people handling tissues of imported cattle and sheep as these animals may occasionally be infected without apparent disease and as this disease can be transmitted by direct contact. Noticeably, cattle and sheep are rarely vaccinated as immunisation is generally applied only after the onset of epidemics (68). However, Seychelles have not imported cattle, goats or sheep for several years.

Malaria

Malaria is endemic in 100 countries and territories and affects 300-500 million people with 2.7 million deaths annually (69). It is the only protozoan disease transmitted by the bite of mosquitoes and it is inoculated by infected *Anopheles*. Due to increasing tourism world-wide, an increasing number of sporadic cases are imported in countries outside of endemic areas. In addition, infected mosquitoes imported by planes can also cause sporadic cases in residents of these countries (70,71). In Seychelles, the only cases of native malaria were reported in 1908 from Aldabra island and in 1930 from Aldabra and Assumption islands (600 miles far from Mahé) where the presence of *Anopheles gambiae* was established (72). Since 1930 and until the present, Seychelles has been free of *Anopheles* mosquitoes and no more native cases of malaria have been observed in the country. Nevertheless, 8-12 malaria cases are diagnosed every year, all imported and mostly in expatriate Indian workers. Considerable efforts are made to prevent the importation of *Anopheles*, for example, systematic insecticide spraying (permethrin 0.5%) in the arriving aeroplanes and ships before landing and on a 400-meter wide area around the international airport and the port.

Conclusion

Seychelles has a low incidence of mosquito-borne diseases. Indeed, rare sporadic cases of dengue fever have been noticed, all without DHF/DSS, no new case of filariasis has occurred for the past 10 years. No clinically diagnosed cases were reported for West Nile, Sindbis or Chikungunya virus infections despite the fact that positive serology has been found. The country is free of yellow fever, Japanese encephalitis, epidemic polyarthritis, and Rift Valley fever. The annual 10 cases of malaria are all imported as Seychelles is free of mosquitoes of the *Anopheles* family.

Table 3 summarises the risk of (re-)emergence of mosquito-borne diseases in Seychelles. Dengue viruses represent the greatest risk for future epidemic with a possible threat for DHF/DSS (considering the Cuban experience). It is likely that previous unnoticed epidemics of West Nile fever have occurred and future epidemics are likely considering that the potential reservoirs and vectors are present in the country. If Seychelles can maintain its socio-economic development, filariasis could almost certainly be eradicated. Native malaria can be prevented by *Anopheles* importation control, which has been successfully implemented so far. Sindbis, Chikungunya, Ross River and Rift Valley viruses may cause outbreaks in Seychelles as their vectors are present, but the risk is probably lower than for dengue and West Nile viruses. Finally, yellow fever and Japanese

encephalitis viruses are serious potential dangers particularly because of their high case-fatality rates and considering that the vectors are present in Seychelles. Mass population vaccination would rid the country of the risk of yellow fever.

Control of the local mosquito populations, prevention of importation of overseas mosquitoes, and isolation from local mosquitoes of suspected human cases (including the availability of bednets) remain the basic necessities to maintain the actual favourable but fragile situation in Seychelles with regards to mosquito-borne diseases.

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