Monitoring and Control of Aedes albopictus, a Vector of Zika Virus, Near Residences of Imported Zika Virus Patients during 2016 in South Korea

Kyu-Sik Chang,1 Gi-Hun Kim,1 Young-Ran Ha,1 Eun Kyeong Jeong,1 Heung-Chul Kim,2 Terry A. Klein,3 Seung Hwan Shin,1 Eun Jeung Kim,4 Seung Jegal,5 Se Jin Chung,6 Young-Ran Ju,1 and Young Mee Jee1*

1Korea Center for Disease Control and Prevention, Osong, Chungbuk, Republic of Korea; 25th Medical Detachment, 168th Multifunctional Medical Battalion, 65th Medical Brigade, Unit 15247, USAF Yongsan, Seoul, Korea; 3Medical Department Activity-Korea/65th Medical Brigade, Unit 15281, USAF Yongsan, Seoul, Korea; 4Seoul Metropolitan Government Research Institute of Public Health and Environment, Seochogu, Seoul, Republic of Korea; 5Gangwon Institute of Health and Environment, Shinbuk, Gangwon, Republic of Korea; 6Incheon Institute of Health and Environment, Jeonggu, Incheon, Republic of Korea

Abstract. Zika virus (ZIKV) is an arthropod-borne virus mainly transmitted by Aedes species. A total of nine of the 16 imported ZIKV reported cases during the mosquito season in the Republic of Korea (ROK), following the return of local nationals from foreign ZIKV endemic countries, were surveyed for Aedes albopictus. Surveillance and vector control of Ae. albopictus, a potential vector of ZIKV, and related species are critical for reducing the potential for autochthonous transmission in the ROK. Surveillance and vector control were coordinated by Korean Centers for Disease Control & Prevention (KCDC) and conducted by local health authorities within 200 m of imported ZIKV patients’ residences. After diagnosis, residual spray for homes and nearby structures (1 x week x 3 weeks), and larval control (3 x week x 3 weeks) were conducted in accordance with national guidelines developed by KCDC in early 2016. Of the nine residences surveyed using BG Sentinel traps, Ae. albopictus trap indices (TIs) for the three (3) patients’ residences located near/inside forested areas were significantly higher than the six patients’ residences located inside villages/urban areas or low-lying farmland without trees. Overall, Ae. albopictus TIs in forested areas decreased by 90.4% after adult and larval control, whereas TIs decreased by 75.8% for residences in nonforested areas. A total of 3,216 Aedes and Ochlerotatus spp. were assayed by real-time polymerase chain reaction for ZIKV, dengue, and chikungunya virus. Both species collected before and after vector control were negative for all viruses. Vector control within 200 m of residences of imported ZIKV patients, conducted in accordance with established guidelines, may have effectively reduced human–mosquito–human transmission cycle by competent vectors in South Korea.

INTRODUCTION

Flaviviruses, for example, dengue virus (DENV) and Zika virus (ZIKV), and Alphaviruses, for example, chikungunya virus (CHIKV), attracted little attention until 2000 when increasingly higher numbers of infections were reported in urban settings throughout much of the tropical and subtropical areas of the world. While Aedes aegypti is the primary vector in most areas, Aedes albopictus, which is present in relatively high numbers in forested areas of the Republic of Korea (ROK), as well as limited urban environments (e.g., where used tires are improperly stored), is considered a secondary vector. Aedes albopictus gained considerable attention in 2016 when > 100 cases were documented human infections.9 While there were occasional cases and outbreaks, its recent adaptation to efficiently infect Ae. aegypti, Ae. albopictus, and several other Aedes spp. in the Pacific Islands has led to its widespread dispersal and outbreaks in many of the tropical and semitropical regions of the world, including nine countries in Asia, 47 in Central and South America, one in North America, 10 in Oceania, and two in Africa, with the potential to spread to temperate regions during “mosquito seasons.”3–6 ZIKV is a monkey-mosquito-monkey forest cycle zoonotic disease that has been adapted to an urban Ae. aegypti–man-Ae. aegypti (and related Aedes species) cycle with the potential for emergence in nonendemic areas where competent mosquito vectors (e.g., Ae. albopictus) are present.7 Worldwide, Ae. aegypti, and Ae. albopictus to a lesser degree because of its broader range of hosts, have been identified as primary and secondary vectors of ZIKV.8 Vector competence studies of Ae. albopictus and Ae. aegypti exposed to the same mice infected by ZIKV showed that the viremia levels in mice produced disseminated infections. However, Ae. albopictus infection rates were more dose dependent, requiring higher blood meal titers than titers required for Ae. aegypti infections.3

Unfortunately, as with other arboviruses, for example, West Nile virus and CHIKV, there are no government approved human vaccines or other specific treatments for ZIKV.10 Therefore, it is essential to implement effective vector control for target species near residences where imported ZIKV-infected patients in the ROK are identified to decrease the potential human-vector-human transmission risks during the late spring to fall mosquito season. An example of this type of approach occurred in Chiba City, Japan, in 2014, when emergency vector surveillance and control strategies of Ae. albopictus were implemented due to local transmission of DENV. The result was that Ae. albopictus populations were significantly reduced after adult control strategies were implemented, which also reduced the risks for future transmission of DENV.11

A total of 16 imported ZIKV cases, including one asymptomatic case, were identified from January to October 2016 in the ROK. Nine of the cases were reported during the primary mosquito season from June to October.12 All ZIKV cases were attributed to transmission by mosquitoes during their travels.
to foreign ZIKV endemic countries, with 77% of the cases attributed to travel to Southeast Asia (Philippines, Vietnam, and Thailand). While the Korean Centers for Disease Control & Prevention (KCDC) has established vector control guidelines for vivax malaria and Japanese encephalitis that are endemic in the ROK, there were no established guidelines for vector control of nonendemic vector-borne diseases, for example, ZIKV, DENV, and CHIKV, imported from tropical and subtropical countries where they are endemic. To reduce the potential for autochthonous transmission of imported mosquito-borne viruses during the mosquito season in the ROK, the KCDC established guidelines in 2016 for the control of *Ae. albopictus*, the primary vector in Korea. However, the efficacies of these guidelines have not been fully evaluated.

**METHODS**

**Patient management.** Returning local nationals and foreigners from endemic countries who demonstrated high fever, rash, and myalgia or arthralgia entering the country or reporting symptoms shortly after arrival were tested for ZIKV. All confirmed ZIKV patients were hospitalized for a period of a few hours to 1 day. The origin of infection was determined through an epidemiological investigation conducted during patient hospitalization. Patients were advised not to enter or go near forested areas, for example, hiking, and to use bed nets while resting/sleeping where mosquitoes were present. Patients who worked or resided near/in forested areas were informed that they should wear long pants and long-sleeved shirts and use repellents for a minimum of 3 weeks after laboratory confirmation of ZIKV infection. Residences were surveyed, and torn window screens repaired and treated daily for 3 weeks with 0.5% permethrin applied by a 2-gallon sprayer.

**Mosquito surveillance near ZIKV patients’ residences.** The KCDC requested the cooperation of the ZIKV-infected patients and their family members in the establishment of mosquito surveillance and control activities that were conducted by the Local Public Health Centers (LPHCs) and Local Environment and Health Institutes (LEHIs). The KCDC provided training to members of the LPHIs and LPHCs on surveillance and control procedures to ensure a harmonized approach by the various groups. After confirmation of ZIKV patient infections during the mosquito season from June to October, the LPHCs conducted surveillance for a 24-hour period twice weekly for 3 weeks when it was not raining at six sites within 200 m of each of the ZIKV patient residences that targeted *Ae. albopictus* using BG Sentinel® traps (Biogents, Regensburg, Germany) (Table 1). After each collection, LPHC personnel placed the adult mosquitoes in a Styrofoam cooler with dry ice, and then transported them to the LEHI laboratories where they were maintained at −70°C. Subsequently, the mosquitoes were transferred to a chill-table (−10°C) and identified to species. *Aedes* and *Ochlerotatus* species were placed in 2-ml cryovials, by species and date and location of the collection, and later assayed for the detection of ZIKV, DENV, and CHIKV.

**RNA extraction of mosquito pools for virus detection.** Mosquito pools were homogenized in 750 μL of RPMI 1640 medium with Tissue Lyser II (QIAGEN, Valencia, CA). The homogenate was centrifuged at 13,000 rpm for 1 minute at 4°C and then 140 μL of the supernatant was subjected to viral RNA extraction. The remaining homogenate was maintained at −70°C for future use. Total RNA was extracted from the mosquito homogenates using Trizol reagent (Invitrogen, Grand Island, NY), in accordance with the manufacturer’s instructions, then resuspended in 50 μL of RNase-free water containing 10 units of RNaseInhibitor (Promega, Madison, WI), and then stored at −70°C until used.

**Detection of ZIKV, DENV, and CHIKV in *Aedes* and *Ochlerotatus* spp. mosquitoes.** A one-step real-time reverse transcription-polymerase chain reaction (RT-PCR) assay for the detection of ZIKV, DENV, and CHIKV in mosquitoes was conducted using a QIAamp Viral RNA Mini kit (QIAGEN Inc., Germantown, MD) for RNA extraction and PowerChek™ Real-time PCR kit (KogenBiotech Co., Ltd, Seoul, Korea) for ZIKV/DENV/CHIKV in accordance with manufacture instructions. Species-specific multiplex primers (forward and reverse) were used to detect ZIKV (JOE), DENV (FAM), and CHIKV (ROX) in accordance with manufactures directions. RT-PCR was performed with 4.2-μL primer/probe mix, 10-μL reaction buffer, 0.8-μL enzyme mix, and 5-μL template RNA. RT-PCR conditions for each reaction were 30 minutes at 50°C, followed by 10 minutes at 95°C, then 15 seconds at 95°C for 40 cycles, and final annealing temperature for 1 minute at 60°C. For positive controls, 5 μL of control mixture (Tris EDTA buffer and Partial fragments of ZIKV, DENV, and CHIKV) was added instead of sample RNA, and for negative control amplification, 5 μL of nuclease distilled water was added instead of sample RNA.

**Adult and larval control of *Aedes* and *Ochlerotatus* spp. near ZIKV patients’ residences.** Nine government ministers held a ZIKV countermeasure meeting in February 2016, where they checked preparatory attitudes and assigned roles to each minister for ZIKV vector control. Guidelines were developed by the KCDC for monitoring and implementation of control measures for *Ae. albopictus* (first edition) and distributed to local governments and related ministers. Vector control agencies of local governments were educated by vector control experts in accordance with the recently developed KCDC guidelines. However, guidelines were drafted based

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**Table 1**

| Case number | Date of collection* | Temperature (°C)‡ | Humidity [%]¶ |
|-------------|---------------------|------------------|-------------|
|             | Pre | Post | Pre | Post | Pre | Post |
| 6           | June 30 | July 21 | 24.6 | 28.3 | 78.1 | 61.3 |
| 7           | July 9 | July 30 | 26.3 | 30.1 | 65.4 | 62.3 |
| 8 (R) and 8 (O)§ | July 13 | August 3 | 26.3 | 29.1 | 69.1 | 65.4 |
| 9           | July 28 | August 18 | 29.7 | 28.9 | 79.0 | 79.3 |
| 10          | August 19 | September 9 | 28.9 | 27.6 | 69.5 | 71.7 |
| 11          | August 26 | September 16 | 24.6 | 23.8 | 82.9 | 84.8 |
| 12          | September 14 | October 5 | 24.5 | 23.3 | 64.1 | 82.0 |
| 13          | September 19 | October 10 | 22.0 | 21.5 | 69.3 | 55.1 |
| 14          | September 23 | October 14 | 21.4 | 20.6 | 57.9 | 61.8 |

*† Date = date of mosquito collection pre and post control.
‡ Temperature and Humidity = daily mean temperature and humidity.
¶ Pre or Post = before and after mosquito control.
§ Case 8 (R) represents case 8 office. Vector control was conducted only near the patient’s residence. Patient 8 (O) reported mosquito bites at his workplace, but only mosquito surveillance was conducted.
Aedes albopictus vector control guidelines, established by the KCDC based on BG Sentinel trap indices (TIs) (number of specimens collected/trap night), were applied for Aedes and Ochlerotatus species control after the confirmation of ZIKV infections among residents returning from endemic areas during the mosquito season (ZIKV cases 6–14, excluding case 8–1) (Table 2). Pesticides were applied using a portable thermal fogger, SS-fog® 150 or 180 (Seshin industrial Co., Seoul, ROK) three times weekly for a period of 3 weeks from 18:00 to 20:00 within 200 m near ZIKV patients’ residences, which included vegetable gardens, ivy-covered walls, and forested areas in parks. Insecticides applied using a thermal fogger included: pyrethroids, for example, Vegadelta® 25EC (2.5% deltamethrin) (Best tech Korea, Suwon, ROK), Greenbug plus® EC (5% etofenprox) (Sip ja sung Inc., Youngin, ROK), and Triplebifen® (5% bifenthrin) (Glory Technical, Yeonggwang, ROK) in accordance with label directions. Pyrethroids were also applied to the walls of ZIKV patients’ homes and nearby structures within 200 m using a 2.6 gallon portable air-compressed residual sprayer (Clover air compressed sprayer® TH-1200; Taehwan Co., Gwangmyeong, ROK) in accordance with label directions.

Larval control was conducted weekly for 3 weeks by removing small artificial containers and water from plant pot bases or using larvicides, for example, Sumilin® 0.5G (0.5% pyriproxyfen) (Catchers Co. Ltd., Kimhae, ROK), Bactosec® [3,500 ITU/mg Bacillus thuringiensis israelensis (Bti)] (Sungin Pharma Co., Damyang, ROK), or Abate® 200E (20% temephos; Pharmcline, Ansan, ROK) to discarded tires and non-removable larval habitats within 200 m of patients’ residences in accordance with label directions. Thermal fogging was not conducted at the residence of ZIKV patient 8–1 because of a privacy request by the patient. Vector control at the residence of ZIKV patient 15 (confirmed ZIKV-positive in mid-October) was not conducted because surveillance did not result in the collection of Aedes albopictus.

Data analysis. Results from surveillance and control were entered into a database and analyzed using the SAS program. Mean values of population densities based on TIs before and after control for the six BG Sentinel traps located within 200 m of each of the residences of the ZIKV patients and with or without nearby forested areas were compared using the T-test in the SAS program. The mean values were determined by applying the following formula in the SAS program:

\[
\text{Mean collection value} = \frac{\text{Number of } A. \text{ albopictus in one trap}}{\text{Number of } A. \text{ albopictus in traps installed at six points}}
\]

Control efficacy of Aedes albopictus was calculated for evaluation using the following formula:

\[
\text{Control efficacy} = 100 - \left( \frac{\text{Number of } A. \text{ albopictus after control}}{\text{Number of } A. \text{ albopictus before control}} \right) \times 100
\]

RESULTS

Imported ZIKV cases in the ROK, 2016. A total of 16 imported ZIKV cases (Philippines [6], Vietnam [4], Thailand [2], Brazil [1], Guatemala [1], Puerto Rico [1], and the Dominican Republic [1]) were identified in ROK residents that had traveled to ZIKV endemic areas in 2016. A total of nine cases were identified from June to September when Aedes albopictus populations are highest (Figure 1, Table 3). Based on patient interviews, infections in all cases were due to mosquito bites. All of the patients, except one asymptomatic case, demonstrated a rash, whereas 14 patients demonstrated one or more of the following symptoms: fever, myalgia, arthralgia, and conjunctivitis (Table 3). For eight of the ZIKV patients, ZIKV was detected in both blood and urine, but was only detected in urine (7) or blood (1) in the other eight cases.

Mosquito surveillance near residences of ZIKV patients before and after vector control. Overall, a total of 9,410 mosquitoes, including 809 Aedes and 496 Ochlerotatus spp. were collected (Table 4). Aedes albopictus was collected in 8/10 residences surveyed where patients were diagnosed with ZIKV from June to September before the implementation of control measures (Table 4). For all residences located in forested and nonforested areas, Culex pipiens complex was the most frequently collected mosquito in BG Sentinel traps, accounting for 19.2–64.1% and 77.6–99.6% of all mosquitoes collected, respectively, followed by Aedes albopictus (19.2–41.0% and 0–7.8%), Ochlerotatus koreicus (0.7–20.3% and 0.03–6.2%), and Culex tritaeniorhynchus (0% and 0.03–85.8%). Aedes albopictus TIs within 200 m of residences near forested areas were significantly higher than those of residences where forested areas were absent. The mean ± SE values of mosquitoes collected in traps for residences located in/near forested and nonforested areas were 29.3 ± 6.50 and 3.1 ± 0.55 (t-value = 1.84, df = 12, P value = 0.0354). The overall

| Table 2 |
| --- |
| Larval and adult control of Aedes albopictus within 200 m near imported Zika virus (ZIKV) patients’ residences during mosquito season in the Republic of Korea, 2016 |
| Mosquito management† | Times‡ | Methods§ | Pesticides¶ |
| Surveillance | 2 times/week | BG-2 sentinel | – |
| Larval control | 1 time/week | Habitat removal, larvicide | Sumilin 0.5G, Abate 200E, Bactosec |
| Adult control | | | |
| Thermal fogging | 3 times/week | Potable thermal fogger | Vegadelta 25EC, Greenbug plus EC, Triplebifen |
| Residual spray | Once at 15 days | Potable residual sprayer | Etovega® EC, Phantom smart® EC |

∗ Mosquito management was conducted for a period of 3 weeks near ZIKV patient residences.
† Number of vector monitoring and control for a period of time.
‡ BG-2 Sentinel mosquito trap (BioQuip products Inc., CA); Potable thermal fogger (SS-fog 150 or 180; Seshin industrial Co.); Potable residual sprayer (Clover air compressed sprayer TH-33).
§ Pesticides included one or more of the following methods: Larval control: Sumilin 0.5G; Pyriproxyfen 0.5%; Insect Growth Regulator, Abate 200E; Temephos 1%; Organophosphate, Bactosec; Bacillus thuringiensis israelensis 31.43%; Adult control: Vegadelta EC; deltamethrin 2.5%; Pyrethroid, Greenbug plus EC, etofenprox 5%; pyrethroid, Triplebifen; bifenthrin 5%; pyrethroid, Etovega® EC, etofenprox 10%; pyrethroid and Phantom smart® EC; etofenprox 10%; pyrethroid.
The mean number of *Ae. albopictus* collected near patient residences before and after vector control were 10.6 and 1.3, respectively, with an effective control rate of 83.1% (Table 5). The mean numbers of *Ae. albopictus* captured near patients’ residences near forested areas before and after vector control were 29.3 and 2.5, respectively, and without nearby forested areas...
Aedes albopictus

Imported Zika virus (ZIKV) cases from Southeast Asia, Africa, South and Central America, and the Caribbean into the Republic of Korea during 2016

| Case number | Confirmation date* | Symptom,$^{†}$ | Country of virus origin | Entry date | Forest area§ | Detection | MM ||
|-------------|-------------------|---------------|------------------------|------------|-------------|----------|---|
| 6           | June 30           | Rs, Fv, Ar, My, Cj | Dominican Republic     | June 23    | Yes         | Blood (−), urine (+) | L, TF, RS |
| 7           | July 9            | Rs, Cj        | Guatemala               | July 6     | No          | Blood (−), urine (+) | L, TF, RS |
| 8 (R) and 8 (O) | July 13       | Rs, Ar        | Puerto Rico             | July 4     | Yes         | Blood (−), urine (+) | L, TF, RS and L, RS |
| 9           | July 28           | Rs, Fv, Ar, My | Vietnam                 | July 15    | No          | Blood (−), urine (+) | L, TF, RS |
| 10          | August 19         | Rs, Fv, My    | Thailand                | August 8   | Yes         | Blood (−), urine (+) | L, TF, RS |
| 11          | August 26         | Rs, My        | Vietnam                 | August 2   | No          | Blood (−), urine (+) | L, TF, RS |
| 12          | September 14      | Rs, Fv, My, Cj | Philippines             | September 6| No          | Blood (−), urine (+) | L, TF, RS |
| 13          | September 17      | Rs            | Philippines             | September 13| No         | Blood (−), urine (+) | L, TF, RS |
| 14          | September 23      | Rs, Ar, My    | Thailand                | September 16| No        | Blood (−), urine (+) | L, TF, RS |

* Date = date of laboratory confirmation.
† Symptoms: Ar = arthralgia; Cj = conjunctivitis; Fv = fever; My = myalgia; Rs = rash.
‡ Mosquito bites were the source of all infections based on an epidemiological investigation of each of the patients.
§ Forested areas within 200 m of a patient’s residence.
| Country of virus origin | Entry date | Forest area§ | Detection | MM |
|------------------------|------------|-------------|-----------|---|
| Thailand               | July 6     | No          | Blood (−), urine (+) | L, TF, RS |
| Vietnam                | August 2   | No          | Blood (−), urine (+) | L, TF, RS |
| Philippines            | September 6| No          | Blood (−), urine (+) | L, TF, RS |
| Thailand               | September 16| No        | Blood (−), urine (+) | L, TF, RS |

were 3.1 and 0.8, respectively, with estimated control rates of 90.4% and 75.8% for residences in/near forested areas and without nearby forests, respectively.

Overall, mean TIs of Ae. albopictus for all residences were significantly lower after 3 weeks of treatment (5.5) when compared with pretreatment levels (14.3) (Table 5). However, while TIs were lower for all residences after treatment, there were no significant differences in the TIs for residences where the initial mean numbers of Ae. albopictus were < 5.0 or at the one residence where control measures were not implemented (Table 5). For patient 8 (R), the mean number of Ae. albopictus collected was 40.0, whereas at 3 weeks after only larval control and residual spray were conducted, the TI was not significantly reduced (34.7).

Detection of ZIKV, DENV, and CHIKV. A total of 686 Ae. albopictus, 123 Ae. vexans nipponii, and 490 Oc. koreicus, and six Oc. togoi were assayed for the presence of ZIKV, DENV, and CHIKV. None of the individually assayed specimens were positive for any of the viruses tested.

**DISCUSSION**

On February 1, 2016, an Emergency Committee was convened by the Director General under the International Health Regulations (2005). Following the advice of the Committee, the Director General announced a recent cluster of microcephaly and other neurologic disorders reported in Brazil to be a Public Health Emergency of International Concern. The Emergency Committee agreed that a causal relationship between ZIKV infection during pregnancy and microcephaly was strongly suspected. The Director General emphasized that the most important protective measures were the implementation of mosquito control to reduce biting populations and the prevention of mosquito bites, for example, proper wearing of clothing and using effective repellents, especially for high-risk individuals, for example, pregnant women.

To prevent mosquito ZIKV transmission within 200 m of the confirmed ZIKV patients’ residences who had recently returned from ZIKV endemic areas, the KCDC, in collaboration with the LPHCs and LEHIs, conducted mosquito-borne disease surveillance and control during the mosquito season in accordance with the newly established guidelines, which demonstrated a relatively high level of efficacy for decreasing vector numbers.

Singapore focused on vector mosquito control from 1960 to 1970 to effectively prevent the spread of DENV that belonged to the family of viruses (Flaviviridae) as ZIKV, which are transmitted principally by Aedes species mosquitoes.

Dengue fever (DF) appeared in Singapore and quickly became a major cause of childhood death as a result of a hemorrhagic syndrome. A public health response to DF began in 1966, when the Vector Control Unit was set up within the Quarantine and Epidemiology Branch, initially in the Ministry of Health but transferred to the Ministry of the Environment in 1972, when...
tochthonous cases of DF, 19 cases were reported.24,25 The Total number (mean and SE) of No forest which showed that vector populations decreased as a result of response focused mostly on personal protection, whereas project to control (implementation of larval and adult trolling the vector populations before the disease was de-
gapore experienced a 15-year period of low dengue incidence and larval source reduction (i.e., reducing the avail-
avable disease in 1977.17 From 1966 to 1968, after a series of entomologic surveys18–22 and a pilot project to control Aedes vectors in an area with high incidence of DF,23 a vector control system based on entomologic sur-
vellence and larval source reduction (i.e., reducing the avail-
ability of Aedes larval habitats) was developed and implemented in 1968.17 Program emphasis was placed on the elimination of mosquito breeding sites to reduce adult populations that precede disease transmission. The hypothesis was that con-
trolling the vector populations before the disease was de-
tected would result in the reduction of transmission. After the implementation of larval and adult Ae. aegypti control, Sin-
gapore experienced a 15-year period of low dengue incidence with < 10 cases annually.

In Japan, after a hiatus of 70 years without confirmed au-
tochthonous cases of DF, 19 cases were reported24,26 The response focused mostly on personal protection, whereas concurrently vector control and surveillance were implemented which showed that vector populations decreased as a result of control strategies.25,26

The TIs for Ae. albopictus, using the BG-2 Sentinel mos-
quitoso traps, were < 10 until May, when TIs rapidly increased more than 100-fold in June. Aeodes albopictus numbers thereafter gradually increased through early September, but then decreased to low levels by late September/early October before disappearing with the onset of the winter season. Aeodes albopictus larval control (removal of larval breeding habitats and use of larvicides) was conducted until May, whereas from June until the end of the mosquito season, both larval and adult control were implemented within 200 m of ZIKV patient residences for 3 weeks after the confirmation of ZIKV infections in ROK travelers. ZIKV is commonly detected in human blood for 3 days after the onset of symptoms, but can be detected in some cases for up to 14 days. While it is possible that Ae. albopictus may bite patients during the incubation period, we were not able to survey patients at the preveirnic stage in South Korea. After feeding on ZIKV infected blood, ZIKV disseminated from the midgut of all Ae. albopictus, and 73% of the mosquitoes had ZIKV in their saliva.27

In the present study, vector control was limited to within 200 m of patient residences, taking into consideration that the flight range of Ae. albopictus is typically < 200 m from the forests edge.28–30 The identification of the major habitats of Ae. albopictus in the ROK is a critical factor for efficient vector control. The mean TIs of Ae. albopictus within 200 m of ZIKV patient residences near and distant from forested areas were significantly lower after control measures were imple-
mented. Although control residences (without vector control) at the one residence where vector control was not implemented, TIs were similar during the 3-week period after diagnosis of ZIKV infection, indicating that the implemented control measures had a significant effect on reducing vector populations.

During 2017, more intensive ZIKV, DENV, and CHIKV con-
trol programs, including vector populations for patient resi-
dences within 200 m of forests are planned. Thermal fogging of nearby bushes/forests demonstrated a high level of effective control for Ae. albopictus adults, most likely, because adults typically rest on the back of leaves in bushes and only emerge from the vegetation when a blood source approaches. In the present study, it was not possible to conduct thermal fogging for the control of adult Ae. albopictus near the office of patient 8 (O) out of respect for the patient’s privacy. However, other types of control, such as larval control and residual spraying, were conducted near the residences of other patients. Nevertheless, the control rate of Ae. albopictus near this patient’s residence was only 13.3%, which was significantly lower when compared with control rates near other patient residences. Although the population density of Ae. albopictus near the residences of pa-
tients 7, 8, 12, and 13 decreased after control, the control rates were not significantly different. This might be attributed to the low pretreatment Ae. albopictus TIs (< 5).

Although the overall mean control rate for Ae. albopictus was 87.7%, potential pesticide resistance should be assessed, thereby facilitating the selection of pesticides for more effective control. All Aedes and Ochlerotatus spp. collected were negative for ZIKV, DENV, and CHIKV. To date, there have been no reports of autochthonous transmission of ZIKV, DENV, and CHIKV in the ROK and only one event of autochthonous transmission of DENV in Japan.10 Accordingly, vector control is essential to efficiently prevent transmission of these three viruses during the summer mosquito season. While the KCDC guidelines for Ae. albopictus control (drafted in 2016) has proven effective for reducing vector populations and potential transmission of ZIKV near residences of ZIKV patients, stricter patient management, for example, in-
creased hospitalization periods, to reduce the potential for transmission at their residences should be considered.

ZIKV vector management near Zika patients’ residences, conducted in accordance with guidelines for Ae. albopictus control established in 2016, significantly reduced vector

### Table 5

| Case number* | Number Ae. albopictus (Mean ± SE)† | Control rates (%)‡ | P value§ |
|--------------|-----------------------------------|--------------------|----------|
| Control      |                                   |                    |          |
| 8 (O)#       | 240 (40.0 ± 0.97a) 208 (34.7 ± 6.16a) 13.3 (0.4566) |                    |          |
| Forest       |                                   |                    |          |
| 10           | 215 (35.8 ± 4.44a) 12 (2.0 ± 1.03b) 94.0 (0.0230)  |                    |          |
| 6            | 137 (22.8 ± 1.87a) 18 (3.0 ± 1.04b) 87.0 (0.0002) |                    |          |
| Mean         | 352 (29.3 ± 6.50a) 30 (2.5 ± 0.50b) 91.0 (0.0305) |                    |          |
| (%, Mean ± SE)** |                    |                    |          |
| No forest    |                                   |                    |          |
| 7            | 16 (2.7 ± 0.33a) 6 (1.0 ± 0.63a) 62.0 (0.0212)   |                    |          |
| 8 (F)        | 10 (1.7 ± 0.75a) 2 (0.3 ± 0.15a) 80.0 (0.1729)  |                    |          |
| 9            | 30 (5.0 ± 1.69a) 14 (2.4 ± 0.33b) 53.0 (0.1557) |                    |          |
| 12           | 21 (3.5 ± 0.92a) 1 (0.2 ± 0.17a) 95.0 (0.0039)  |                    |          |
| 13           | 17 (2.8 ± 1.91a) 2 (0.3 ± 0.21a) 88.0 (0.2335) |                    |          |
| Mean         | 94 (3.1 ± 0.55a) 25 (0.8 ± 0.42b) 74.0 (0.0069) |                    |          |
| (%, Mean ± SE)** |                    |                    |          |
| Total (mean)** | 446 (10.6 ± 5.04a) 55 (1.3 ± 0.43b) 82.5 (0.0354) |                    |          |

SE = standard error.
* Aedes albopictus were not collected at residences of ZIKV patients 11 and 14.
† Means within a row and column followed by the same letter are not significantly different (P < 0.05, T-test) (six replicates).
‡ Control rates = 100 × [Number of Ae. albopictus after control/Number of Ae. albopictus before control] × 100.
§ P value significant at < 0.05.
* Before control: Number of Ae. albopictus collected in six traps during 1 day before control.
† After control: Number of Ae. albopictus collected in six traps during 1 day and 3 weeks after first collection.
# 8 (O): Forest area. No chemical control, such as residual spray and thermal fogging, was conducted due to personal information protection and type of office equipment.
** Total (mean): Overall total number collected and mean number collected for residences located in near forests and residences located in areas without trees before and after treatment. Number of Ae. albopictus collected for case 8 (O) was not included.
populations when precontrol TIs were > 5. Thus, control measures implemented in accordance with the KCDC vector control guidelines may effectively reduce the potential for autochthonous transmission of not only ZIKV but also DENV, and CHIKV in the ROK. Although ZIKV, DENV, and CHIKV have not been detected in Aedes spp. or other potential vectors in the ROK, the KCDC must remain vigilant by monitoring patients with suspected mosquito-borne diseases to reduce the potential of viral transmission to resident populations. Arbovirus vector control can be effectively accomplished through the strengthening of national and local government relationships and coordination for the implementation of effective vector control strategies.

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Authors’ addresses: Kyu-Sik Chang, Gi-Hun Kim, Young-Ran Ha, Eun Kyeong Jeong, Seung Hwan Shin, Young-Ran Ju, and Young Mee Jee, Korea Center for Disease Control and Prevention, Osong, Chungbuk, Republic of Korea, E-mails: cks109101@icloud.com, kgh7895@korea.kr, hide3107@korea.kr, juranli@korea.kr, and jeey62@korea.kr.

Heung-Chul Kim, 5th Medical Detachment, 168th Multifunctional Medical Battalion, 65th Medical Brigade, Unit 15247, USAG Yongsan, Seoul, Korea, E-mail: terry.a.klein2.civ@mail.mil. Terry A, Klein, Medical Department Activity—Korea/65th Medical Brigade, Unit 15281, USAG Yongsan, Seoul, Korea, E-mail: terry.a.klein2.civ@mail.mil. Eun Jeung Kim, Seoul Metropolitan Government Research Institute of Public Health and Environment, Seochogu, Seoul, Republic of Korea, E-mail: ejvet@daum.net. Seung Jegal, Gangwon Institute of Health and Environment, Shinbuk, Gangwon, Republic of Korea, E-mail: jsjeungil@korea.kr. Se Jin Chung, Incheon Institute of Health and Environment, Joonggu, Incheon, Republic of Korea, E-mail: sejin47@korea.kr.

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