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Original Article

Epidemiological Characteristics of Rabies in South Korea from January 2004 to March 2011

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Over the seven years from January 2004 to March 2011, 105 rabies cases in three different animal species and one case in human were recorded in South Korea. Forty three (40.6%) cattle and 33 (31.1%) dogs, 29 (27.4%) raccoon dogs were affected and one (0.9%) death in human was reported. The highest annual incidence of rabies was recorded with 27 cases in 2004, and then decreased to a median of 14 cases per year. Eighty cases (76.2%) occurred in Gangwon and 24 cases (22.9%) in Gyeonggi and one case in Seoul Province. All rabies cases occurred in the northern part of the country, namely, Seoul, Gyeonggi and Gangwon Provinces. Since 2007, rabies cases were not reported in Gyeonggi Province, but continued to occur and move eastward in Gangwon Province. The monthly distribution of animal rabies during the seven year period peaked in January, and the incidence was the highest during winter, from December to February, and the least common in summer, from June to September. The epidemiological study indicated that preventive measures including distribution of bait vaccine for the control of rabies in wild animals was helpful to a substantial decrease in number of rabies cases in South Korea.

Key Words: Epidemiology, Rabies, Prevention, Raccoon dogs

INTRODUCTION

Rabies is one of the most important infectious and fatal diseases in animals and human and is present in most parts of the world. According to the World Health Organization (WHO), rabies infections result in approximately 55,000 human deaths worldwide every year (1, 2). The disease remains a global concern in warm-blooded hosts, including human and various domestic and wild animals, and is a zoonosis that continues to spread through reservoirs. In South Korea, the animal rabies has been controlled by the National Veterinary Research and Quarantine Service (NVRQS) and the local Veterinary Service Laboratories (VSL).

Since the first rabies case was reported in a dog in 1907, a number of rabies had been identified in several provinces of South Korea up to 1945 (3). As a result of the application of intensive vaccination program using inactivated or live attenuated rabies vaccines, removal of stray dogs, and education for people, a steady decrease in the number of rabies cases from 1946 to 1984 was observed, and no case was reported for eight years from 1985 to 1992 (4, 5). Then, a recurrence of the disease was noted in Gangwon Province in 1993, and a continuous increase of rabies cases was observed during the period 1993~2003 (364 cases).

It is well known that rabies is transmitted by the red fox and raccoon dogs in Europe and Russia, and by foxes, skunks, and raccoons in North America. As the epidemiolo-

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gical study reported that wild animals including raccoon dogs (*Nyctereutes procyonoide*) and badgers (*Meles meles*) played a key role in transmitting rabies to cattle and dogs in South Korea, Korean government made a decision to distribute vaccinia-rabies glycoprotein (V-RG) bait vaccine in 2000 (6, 7). Over three million bait vaccines have been distributed to the occurrence regions in order to prevent rabies by contact of rabid raccoon dogs (8). Although national vaccination to domestic and pet animals has blocked dog to dog transmission (urban rabies), rabies cases in wild animals (sylvatic rabies) are not eradicated.

The incidence of rabies was assessed and the epidemiological characteristics of the disease were evaluated to help eradication of rabies in South Korea. The aim of this study was to describe the recent rabies situation and to provide epidemiological information for the last seven years from January 2004 to March 2011 in South Korea.

MATERIALS AND METHODS

Collection of data

Data related to all animal rabies cases that had been reported to NVRQS of Korea from January 2004 to March 2011 were collected. Data on a human rabies case during the same period were collected from the Korea Center for Disease Control and Prevention (KCDC). Only laboratory confirmed cases were included in the analysis.

Samples from domestic and wild animals

Rabies-suspected domestic and wild animals were provided by farmers, owners, and private and provincial veterinarians, and then samples were sent to VSL and NVRQS. The origin and behavior of animals were recorded and, if they were alive, their clinical signs were observed for at least 14 days. All rabies-suspected cases were diagnosed by indirect fluorescent antibody test (FAT) according to the Manual of Diagnostic Tests and Vaccines for Terrestrial Animals (9), and histopathological test and reverse transcriptase polymerase chain reaction (RT-PCR) test as the supplementary diagnostic methods were also performed to detect Negri bodies or virus RNA in infected tissues (10, 11).

Indirect fluorescent antibody test (FAT)

The FAT was performed according to the procedure described by OIE and WHO (1, 9). In brief, frozen thin sections of the Ammon's horn tissue on slide were fixed in cold acetone (-20℃) for 20 min. After three successive wash with phosphate buffer saline (PBS, pH 7.2), the slides were reacted with specific monoclonal antibody (JenoBiotech, Chuncheon, Korea) against rabies for 45 min at 37℃, and then stained with fluorescence isothiocyanate (FITC) conjugated goat-anti mouse IgG+IgM. After rinsing with PBS, the slides were air-dried and applied with mounting buffered glycerin (Southern Biotechnology Associate, Birmingham, USA). The slides were examined under cover slips at 400× using a fluorescent microscope (Nikon, Tokyo, Japan). Positive and negative controls were run together with the test samples. The slide showing specific fluorescence was confirmed as positive (12, 13).

Spatial and statistical analyses

Locations of rabies cases were depicted on the map. The location of each outbreak site (or farmhouse) was identified using the data from NVRQS, and indicated as a single point

Table 1. Reported rabies cases in human and animals in South Korea from January 2004 to March 2011

Year	2004	2005	2006	2007	2008	2009	2010	2011	Total (%)
Human	1	0	0	0	0	0	0	0	1 (0.9)
Cattle	7	4	10	2	3	12	5	1	43 (40.6)
Dog	10	8	5	0	4	1	4	0	33 (31.1)
Raccoon dog	9	2	4	1	7	5	1	0	29 (27.4)
Total (%)	27 (25.5)	14 (13.2)	19 (17.9)	3 (2.8)	14 (13.2)	18 (17.0)	10 (9.4)	1 (0.9)	106 (100)

on the map using Map Wizard for Excel (Tastech, Seoul, Korea). The chi-square test was performed to demonstrate the association between season and rabies cases.

RESULTS

Number of rabies cases

A total of 106 rabies that were confirmed in South Korea from January 2004 to March 2011 included a single case in human (0.9%, 1/106) and 43 cases in cattle (40.6%), 33 cases in dogs (31.1%), and 29 cases in raccoon dogs (27.4%), respectively (Table 1). The highest annual incidence of rabies was recorded with 27 cases in 2004, and then decreased to a median of 14 cases per year.

Table 2. Number of animal rabies recorded in Seoul, Gyeonggi and Gangwon Provinces from January 2004 to March 2011

Year	Seoul	Gyeonggi	Gangwon	Total
2004	0	7	19	26 (24.8)
2005	0	6	8	14 (13.3)
2006	1	11	7	19 (18.1)
2007	0	0	3	3 (2.9)
2008	0	0	14	14 (13.3)
2009	0	0	18	18 (17.1)
2010	0	0	10	10 (9.5)
2011	0	0	1	1 (1.0)
Total (%)	1 (1.0)	24 (22.9)	80 (76.2)	105 (100)

Regional prevalence of rabies

The disease was confined to the northern part of South Korea, i.e., Seoul, Gyeonggi and Gangwon Province. Only one case (1%) was reported in Seoul, 24 cases (22.9%) in Gyeonggi and 80 cases (76.2%) in Gangwon Province (Table 2). Two Provinces (Gyeoggi and Gangwon Provinces, except Seoul) are located near the border of the demilitarized zone (DMZ) and the disease outbreaks continued to move eastward in Gangwon Province. Figure 1 shows the spatial locations of positive animal rabies cases in South Korea from 2004 to 2011. In Gyeonggi Province, the disease was reported in six counties (Yangju, Paju, Younchun, Pochun, Gimpo, and Yangpyung) from 2004 to 2007, and then no more cases were reported until March 2011 (Fig. 2A). In Gangwon Province, the disease was reported in seven counties (Chuncheon, Hongchon, Goseong, Yanggu, Inje, Chulwon and Hwachen) from 2004 to 2007, and then moved

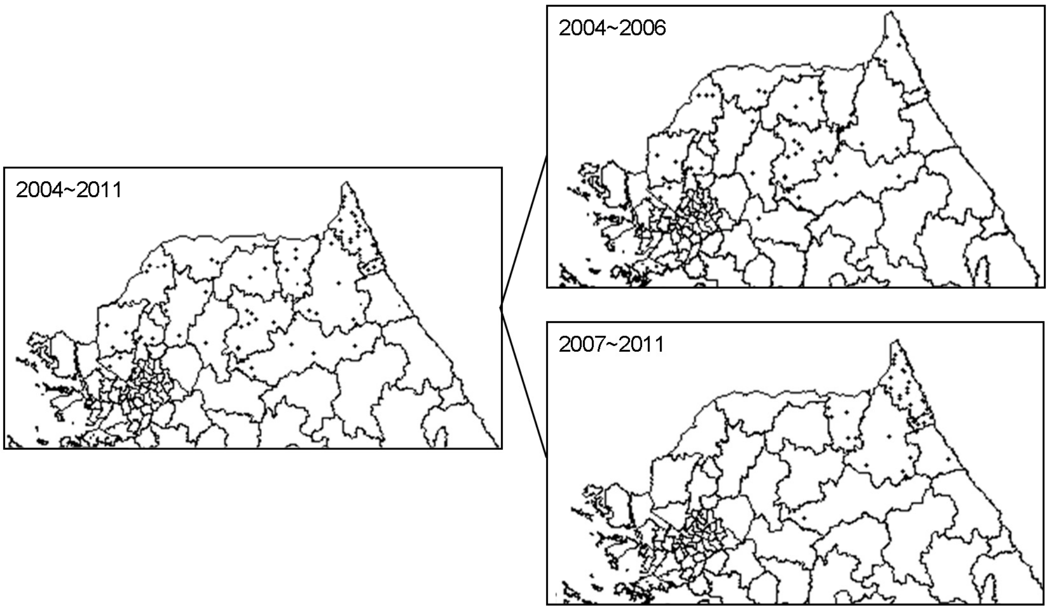

Figure 1. Distribution of rabies cases in South Korea from January 2004 to March 2011. A dot indicates the site of the incidence of rabies. It is notable that the disease outbreaks continued to move to the eastern part of Gangwon Province between 2007 and 2011.

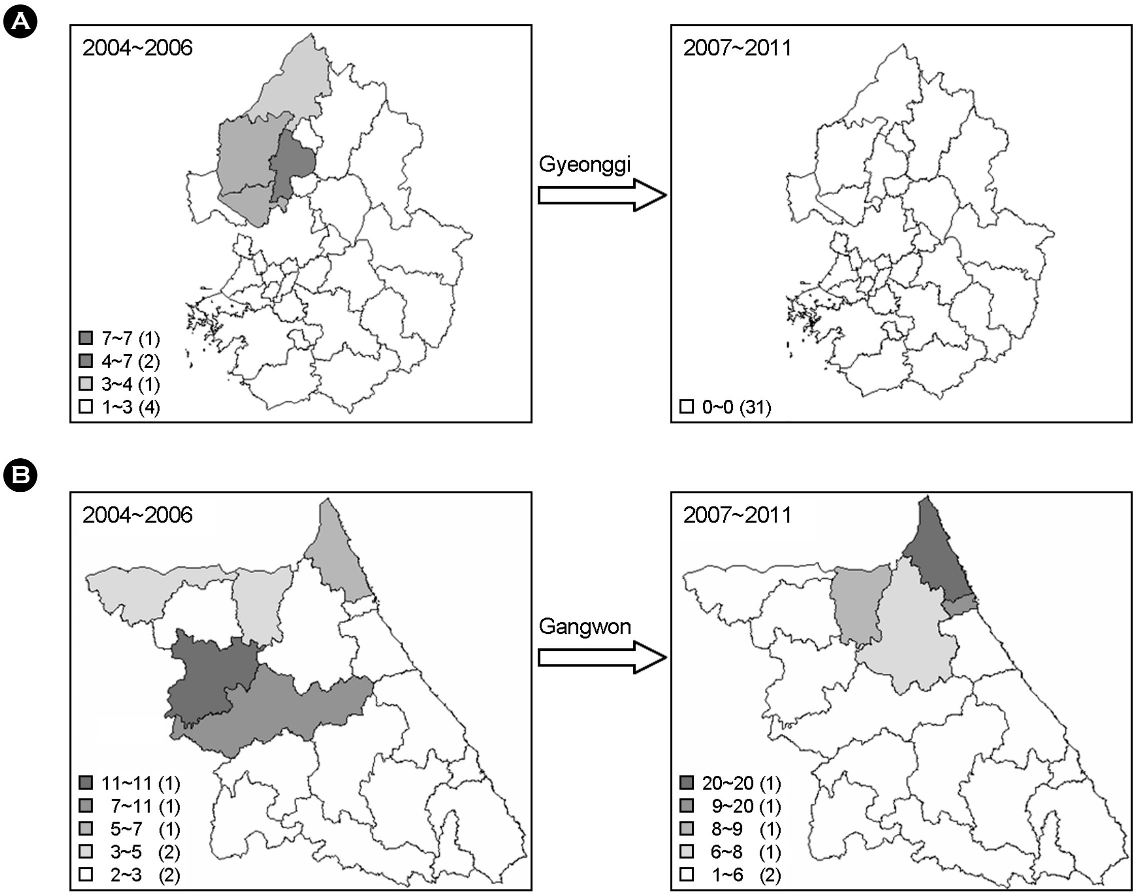

Figure 2. Change of rabies incidences in Gyeonggi and Gangwon Province. The rabies incidence was significantly decreased in Gyeonggi Province (A). In Gangwon Province, the rabies cases were decreased and the outbreak regions were moved into the eastern part (B).

to the six counties (Goseong, Sokcho, Yanggu, Inje, Yangyang and Hongchon) which are located in the eastern part of Gangwon Province from 2007 to 2011 (Fig. 2B).

The seasonal distribution of rabies

The seasonal distribution of animal rabies cases is shown in Table 3; 31 cases (29.5%) occurred in spring (March to May), 13 cases (12.4%) in summer (June to August), 23 cases (21.9%) in autumn (September to November) and 38 cases (36.2%) in winter (December to February). Given that the expected seasonal incidence was even, the reported cases and season are highly correlated (χ^2 = 13.21, p = 0.004), being above the expected value during spring and winter and below the expected values during summer. When the monthly distribution of animal rabies was analyzed, the highest incidence occurred in January and February and the lowest incidence occurred between June and September (Fig. 3).

Table 3. Seasonal distribution of animal rabies in South Korea from January 2004 to March 2011

Season (month)	Number of cases^{a,b} (%)
Spring (March-May)	31 (29.5)
Summer (June-August)	13 (12.4)
Autumn (September-November)	23 (21.9)
Winter (December-February)	38 (36.2)
Total	105 (100)

[a]It was assumed that the expected seasonal incidence (26.25) was even.
[b]χ^2 = 13.21, p = 0.004.

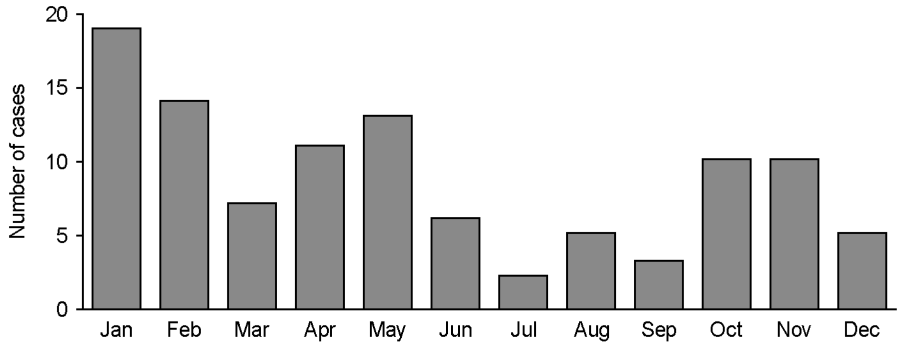

Figure 3. Total monthly distribution of animal rabies cases in South Korea from January 2004 to March 2011.

DISCUSSION

The rabies cases for the last seven years from January 2004 to March 2011 in South Korea were updated. Between 2004 and 2011, a total of 105 animal rabies occurred in cattle, dogs and raccoon dogs and a single case of human rabies occurred in Gyeonggi Province. The human bitten by a rabid dog that had contacted with rabid raccoon dog died in 2004. Since 2000, a total of five people died from human rabies. Four cases of them occurred in Gyeonggi Province and one case in Gangwon Province between 2001 and 2003 (5). No more human rabies occurred between 2005 and 2011. This decline of human rabies may in part be in parallel with initiation of active post exposure prophylaxis (PEP) treatment on bitten patients and of including preventive measures including nation-wide education on rabies by Korean government.

As shown in Table 1, the highest number of cattle rabies (40.6%) was confirmed in 2004~2011. This situation has not changed since 1993, because cattle have more opportunity to make contact with rabid wild animals. On the other hand, raccoon dog rabies was first identified in Gyeonggi Province in 1994 (4). The number of rabies case in raccoon dogs has increased for about 20 years; 44 cases (12.1%) in 1993~2003 (5), 29 cases (27.4%) in 2004~2011, indicating that sylvatic rabies has predominated in South Korea.

After the recurrence in 1993, the annual rabies seemed to be decreased in 2004~2011, especially in Gyeonggi Province and there was no more occurrence of rabies from 2007 to 2011. Also, the occurrence was restricted to some counties of Gyeonggi and Gangwon Provinces near the DMZ. The decline of animal rabies and spatial outbreaks in limited area may be attributed to the initiation of the national rabies eradication program (NREP) that covers nation-wide annual vaccination of dogs and cattle against rabies in along with the distribution of bait vaccines for raccoon dogs. In addition, the continuous vaccination campaign and education for people have been implemented. The other reason would be lowered population in raccoon dogs acting as a key player in circulation of rabies in natural area due to parasitic disease and rapid urbanization (8, 14).

Between 2007 and 2011, rabies had only occurred in the eastern part of Gangwon Province. Recently, we have reported that the seropositive rates of dogs for rabies vaccination differed depending on the provinces and demonstrated that Gangwon Province exhibited the lowest seroprevalence (15). It is thus likely that low levels of rabies antibody seroprevalence could be, at least in part, responsible for the frequent outbreaks in the Gangwon Province.

Previous study reported that rabies showed a cyclic behavior with outbreaks occurring every four years from 1993 to 2003 in South Korea (5). The cyclic fluctuations were seen in dogs and also reported in foxes and black-backed jackals (5, 16). This might be in part related to natural population density fluctuations in animals (17). In South Korea, the cyclic outbreaks occurring every four years might also be the reflection of population of raccoon dogs which are a major transmitter of rabies (18, 19). However, our study revealed that the cyclic outbreaks were not observed from 2004 to 2011. We assume that this might be a consequence of the distribution of bait vaccine; 220,000 baits were distributed in the Gyeonggi and Gangwon Provinces in 2005 (uptake rate: 89.3%), 224,800 baits in 2006 (89.7%), 271,000 baits in 2007 (94.0%), 390,100 baits in 2008 (82.6%), and 350,280 baits in 2009 (86.9%), respectively (unpublished data).

During the years of 2004~2011, rabies cases in Korea were frequently observed in January to February. The raccoon dogs are the only canid known to hibernate in winter and also known as omnivorous animal that feeds mainly on wild mice, reptiles, amphibians, insects, fruit, sweet potatoes and fish. The highest incidence in winter may, in part, relate to raccoon dogs foraging foods near villages and in rural areas. In case they cannot accumulate enough fat in their body for hibernation, they tend to come down to village to seek food (5, 6). In addition, raccoon dogs may awaken during the hibernation in winter due to the warm weather caused by recent climate change or global warming. Indeed, it has been reported that raccoon dogs often wander around the chicken farm or military unit during the winter for food (20). Therefore, domestic animals are likely to be exposed to rabid raccoon dogs, especially during winter time. The rabies seasonality is similar to that of results obtained from 1993 to 2003 (5). In contrast, this seasonal pattern is relatively low in the summer season due to the food availability around their wild shelters.

Previous studies reported that, 21 of 67 captured or dead Korean raccoon dogs were positive for rabies and their geographical distribution was almost identical to the areas where cases occurred in cattle and dogs (6, 21). Therefore, raccoon dogs may be the major transmitter of rabies in South Korea. To eradicate rabies transmitted by raccoon dogs, trap-vaccinate-release (TVR) and point infection control (PIC) programs can be applied to wild animals in South Korea in the near future. However, both TVR and PIC are known as labor intensive and the most expensive tactics per unit area. In contrast, oral rabies vaccine (ORV) program is regarded as a cost-effective measure and reported to yield benefits in North America (22). In South Korea, ORV program has been implemented and resulted in decreasing rabies in wild animal, which ultimately has positive effects on public health. However, new model program concerning wild animals needs to be implemented to completely eradicate rabies. In conclusion, this study evaluated the epidemiological characterization of rabies in Korea that will definitely impact on improvement of public health.

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