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Short communication

Virulence characteristics of *Yersinia pseudotuberculosis* isolated from breeding monkeys in Japan

Taketoshi Iwata [a], Yumi Une [b], Alexandre Tomomitsu Okatani [b], Yukio Kato [b], Aya Nakadai [a], Ken-Ichi Lee [a], Maiko Watanabe [a], Takahide Taniguchi [a], AbdelAzim Elsayed Elhelaly [a], Yoshikazu Hirota [a], Hideki Hayashidani [a,*]

[a] *Division of Animal Science, Institute of Symbiotic Science and Technology, Tokyo University of Agriculture and Technology, 3-5-8 Saiwai-cho, Fuchu, Tokyo 183-8509, Japan*
[b] *School of Veterinary Medicine, Azabu University, 1-17-71 Fuchinobe, Sagamihara, Kanagawa 229-8501, Japan*

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Abstract

Between April 2001 and 2007, 18 *Yersinia pseudotuberculosis* outbreaks occurred in breeding monkeys at 12 zoological gardens in Japan, and 28 monkeys of 8 species died. A total of 18 *Y. pseudotuberculosis* strains from the dead monkeys, comprising one strain per outbreak, were examined for serotype and the presence of the virulence genes *virF*, *inv*, *ypm* (*ypmA*, *ypmB* and *ypmC*) and *irp2*. Of the 18 *Y. pseudotuberculosis* strains, 7 (38.9%) were serotype 4b, 7 (38.9%) were serotype 1b, and there was one each of serotypes 2b, 3, 6 and 7. All the 18 strains examined harbored *virF* and *inv*. Sixteen (88.9%) strains, including the strain of serotype 7, harbored *ypmA*. However, no strain harbored *ypmB*, *ypmC* and *irp2*.

This study demonstrated that among other pathogenic factors, almost all the *Y. pseudotuberculosis* isolated from the outbreaks had the *ypm* gene encoding the superantigenic toxin, YPM. As most of the monkeys who died in those outbreaks originated from South America and other regions, where the presence of the *ypm* gene have not been reported, YPM might be the cause, or at least the most important factor for, the high mortality of the breeding monkeys infected by *Y. pseudotuberculosis* in Japan. This is also the first report of a fatal case due to *Y. pseudotuberculosis* serotype 7 infection in the world.

Keywords: *Yersinia pseudotuberculosis*; Breeding monkey; Virulence genes; YPM

1. Introduction

Yersinia pseudotuberculosis is known to be an important causal agent of zoonosis. Monkey species are especially sensitive to *Y. pseudotuberculosis*, and many fatal cases of *Y. pseudotuberculosis* infection in

* Corresponding author. Tel.: +81 42 367 5775; fax: +81 42 367 5775.
E-mail address: eisei@cc.tuat.ac.jp (H. Hayashidani).

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breeding monkeys have been reported throughout the world, including in Japan (Buhles et al., 1981; Hirai et al., 1974; Kageyama et al., 2002; MacArthur and Wood, 1983; Maruyama et al., 1983; Murata and Hama, 1992; Rosenberg et al., 1980; Sasaki et al., 1996; Taffs and Dunn, 1983; Une et al., 2003). Affected monkeys may die unexpectedly or after a very short illness, and at the present time there is no effective preventive method against *Y. pseudotuberculosis* infection. Therefore, monkey *Y. pseudotuberculosis* infection poses a serious problem for zoological gardens engaged in monkey breeding.

The pathogenicity of *Y. pseudotuberculosis* is associated with several virulence factors. Pathogenic strains of *Y. pseudotuberculosis* harbor 70-kb virulence plasmid (pYV), which encodes a number of important virulence and virulence-associated proteins. Additionally, a high-pathogenicity island (HPI), encoding an iron uptake system represented by its siderophore yersiniabactin (Carniel, 1999), and *Y. pseudotuberculosis*-derived mitogen (YPM), which is a superantigenic toxin, are known to play important roles in causing severe systemic infection (Abe et al., 1997). However, it remains unclear which virulence factor is connected with the high mortality of monkeys in *Y. pseudotuberculosis* infection. In the present study, we investigated the characteristics of *Y. pseudotuberculosis* isolated from dead breeding monkeys in Japan.

2. Materials and methods

2.1. Bacterial strains

Eighteen *Y. pseudotuberculosis* strains isolated from monkeys that died in 18 outbreaks (one strain per outbreak) were analyzed. These outbreaks occurred between April 2001 and 2007 at 12 zoological gardens (A–L) in Japan, and a total of 28 monkeys of 8 species, comprising 19 squirrel monkeys (*Saimiri sciureus*), 2 hamadryas baboons (*Papio hamadryas*), 2 white-faced sakis (*Pithecia pithecia*), 1 agile gibbon (*Hylobates agilis*), 1 dusky leaf monkey (*Presbytis obscurus*), 1 orangutan (*Pongo pygmaeus*), 1 ring-tailed lemur (*Lemur catta*) and 1 ruffed lemur (*Varecia variegata*), died (Table 1). Pathological findings such as swelling of the Peyer's patch and abscesses in the spleen and liver were typical of yersiniosis. Outbreaks occurred two, three and four times in the zoological gardens C, H and G, respectively.

Table 1
Sources of *Y. pseudotuberculosis* isolated from breeding monkeys in Japan

No.	Strain	Institution	Region	Isolation month year	Source (number and species of other monkeys dead in the same outbreak)
1	NP011001	A	Kanto	April 2002	Squirrel monkey
2	NP031103	B	Kanto	November 2003	Orangutan
3	NP031101	C	Kanto	November 2003	Squirrel monkey (1 squirrel monkey)
4	NP050101	C	Kanto	January 2005	Squirrel monkey
5	NP070401	D	Kanto	April 2007	Dusky leaf monkey
6	NP031201	E	Kinki	December 2003	Squirrel monkey (2 squirrel monkeys)
7	NP040301	F	Chugoku	March 2004	Squirrel monkey
8	NP010401	G	Sikoku	April 2001	Squirrel monkey
9	NP030401	G	Sikoku	April 2003	Squirrel monkey
10	NP050102	G	Sikoku	January 2005	Squirrel monkey
11	NP051201	G	Sikoku	December 2005	Squirrel monkey
12	NP020501	H	Kyusyu	May 2002	Squirrel monkey
13	NP030601	H	Kyusyu	June 2003	Squirrel monkey
14	NP070201	H	Kyusyu	February 2007	Squirrel monkey
15	NP030701	I	Kyusyu	July 2003	Squirrel monkey (1 squirrel monkey)
16	NP050201	J	Kyusyu	February 2005	Hamadryas baboon (1 hamadryas baboon and 1 agile gibbon)
17	NP050301	K	Kyusyu	March 2005	Squirrel monkey (1 squirrel monkey)
18	NP050303	L	Kyusyu	March 2005	White-faced saki (1 white-faced saki, 1 ruffed lemur and 1 ring-tailed lemur)