

Full Length Research Paper

Factors associated with endemicity of *Yersinia pestis* in Namwala District of Zambia

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Plague which is a flea borne zoonotic disease of mammals caused by the bacterium *Yersinia pestis* has occurred in Eastern and Southern parts of Zambia as epizootics. This study was conducted to determine factors associated with these outbreaks. The study was done in Namwala district of Zambia and a cross-sectional study design was used. The two stage cluster sampling technique was used. The first stage involved conveniently identifying the 8 villages where human cases of plague had been reported. The second stage was random selection of households within the villages. These were sampled without prior knowledge of whether the household had a case of human plague or not. The sampling unit was the households. A total of 45 households were sampled. Twenty six (42%) of the households reported to have had a human case. The mean age of these cases was 10.86 ± 6.74 years while 74% of these were males. The households who reported cases and those who did not report cases were not different in bush activities they were involved in, type of housing they lived in and in terms of floors of their respective houses. The households reporting cases as compared to those who did not report cases were more likely to have rodents with plague found in their surrounding (94.7% vs 73.1%), have dirty surroundings (84.2% vs 50%), have a radius of ≤ 20 meters as nearest human dwelling (94.7% vs 53.8%) and have unplastered walls of their houses (84.2% vs 38.5%) ($P < 0.05$). The entry of infected rodents with fleas to the human habitat and the contact of fleas with humans contribute to the outbreak of plague under conditions which favour survivor of fleas like unplastered houses, dirty surroundings and the existence of infected rodents within a household surrounding of 20 m or less. Employing measures which minimizes the contact between fleas and humans can reduce outbreaks.

Key words: Endemicity, *Yersinia pestis*, Namwala District, Zambia.

INTRODUCTION

Plague is a flea-borne zoonotic disease of mammals caused by the bacterium *Yersinia pestis* which has an incubation period of 2 to 6 days in humans. Rodents are primarily infected by plague and act as reservoirs (Butler,

2000; Perry and Fetherston, 1997). Certain species of rats, prairie dogs, vole, mouse, squirrels, dogs, cats, and rabbits are also suspected to be reservoirs (Guiyole et al., 1994; Perry and Fetherston, 1997). Generally, Y.

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pestis is maintained in populations of wild rodents and their fleas as an obligate parasite, which has been recovered from over 200 mammalian species worldwide (Gasper and Watson, 2001). There are three principal clinical presentations of plague namely bubonic, septicaemic and pneumonic plague. It has a very high fatality rate of 50 to 60% if left untreated. At the moment, plague circulates in rodent populations on five continents except Australia and Antarctica (Butler, 2000). Most human cases of plague are reported from developing countries in Asia and Africa. In Africa, plague foci are distributed throughout the continent (Mwase et al., 1999).

Transmission may occur in several ways with the most efficient involving the ingestion of the organism by the flea during a blood meal from a bacteremic host (Bacot and Martin, 1914). Transmission of *Y. pestis* from fleas to humans occurs primarily via the bites of infected fleas (Perry and Fetherston, 1997). Human to human transmission occurs in pneumonic plague which is highly infectious and rapidly fatal (Wren, 2003). This is where the spread occurs via the respiratory droplets between humans; however this type of epidemic is currently uncommon due to the advent of effective antibiotics and modern public health measures. The other mode of transmission is by inhaling droplets expelled by the coughing of a plague-infected animal (Doll et al., 1994). This can result in plague of the lungs (plague pneumonia).

In Zambia, plague has been reported in Lusaka, Eastern, Western, Northwestern and Southern regions (Mwase et al., 1999) and currently it has occurred in the Eastern and Southern parts of the country as periodic epizootics (Hang'ombe et al., 2012). The first confirmed major outbreak of plague in Zambia was in the Southern region of Namwala district in December, 1996 to February, 1997, where 267 human cases were reported, and 26 people died (Hang'ombe et al., 2012). Following this major outbreak, cases are being reported on an annual basis. This study was conducted in Kabulamwanda area of Namwala district where isolated cases were reported in 2012 and rats were confirmed as harbouring plague. This is according to information obtained from the Namwala District health office in Zambia. The study was undertaken to determine the factors associated with plague in this area.

MATERIALS AND METHODS

Study area

The study was conducted in Kabulamwanda area of Namwala district in the Southern province of Zambia where outbreaks are reported annually. Eight villages of Kabulamwanda where the disease usually occurs annually were included in the study. The villages sampled included Nacubi, Nalubwe, Njiri, Shamani, Shimalambwe, Shimuhila, Shimusashi and Shitongo. Some ongoing studies in the area have confirmed the presence of *Y. pestis* in these areas sampled (Hang'ombe et al., 2012).

Sampling

A cross-sectional study design was employed and the two stage cluster sampling technique was used. The first stage involved conveniently identifying the villages where human cases of plague had been reported. The second stage was random selection of households within the villages. These were sampled without prior knowledge of whether the household had a case of human plague or not. The sampling unit was the households. The sampled houses were 45. From these households 19 were reported to have had cases while 26 did not have any cases. The non cases acted as controls for this study.

Survey

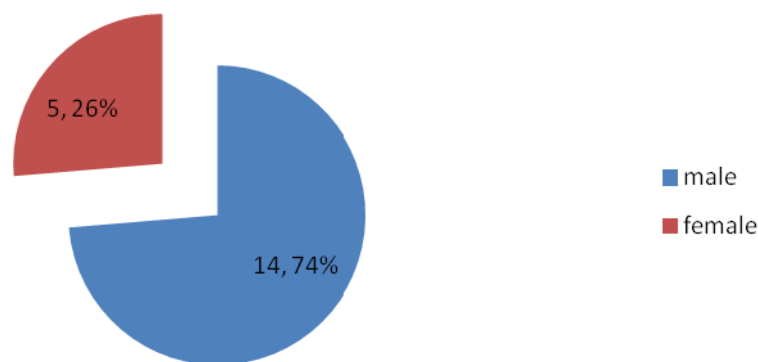
The questionnaire was administered by interviewing household members in different households. Apart from enquiring whether there was a plague case(s) reported on a particular household, the survey also addressed environmental variables such as hut specifications, movements of rodents in or around the huts after farm harvesting and during the rainy season, and basic human behaviors. Hut specifications included; type of houses (mud or brick and plastered, mud or brick and not plastered) and type of floor (mud and temporal, concrete and permanent). Human behavior questions included activities done by the household members either in the bush or plains (such as cattle herding, collection of firewood and poles or activities that allow an individual to venture out in the bush or forest). Moreover, plague control/prevention measures practiced by different households and when these measures are implemented was also noted. Knowledge on the treatment of plague was also assessed for different households. Age and sex variables were only recorded for the plague cases. Observations were also made on the cleanliness of the households and their respective surroundings. Clean surrounding was classified as having a radius of 20 m or more within the house which was clean and cleared, while a clean radius of 20 m or less were classified as having dirty surrounding. Coordinates (latitude and longitude) together with the altitude of each particular household were measured by global positioning system (GPS) reader and recorded.

RESULTS

A total of 45 households were sampled from the 8 villages in Kabulamwanda area of Namwala district. From Table 1, the reported numbers of human cases were 19, thus 42.2% of the sample. The mean age of the cases was 10.86 ± 6.74 years. Of the households sampled 16 (35.6%) had a clean surrounding while 29 (64.4%) had a dirty surrounding. Twenty nine households (64.4%) were involved in cattle herding and collection of firewood while 9 (20%) were involved in other activities in the bush/plains. Seventy four percent of the cases were males while 26% were females (Figure 1). Table 2 shows that thirty seven (82.2%) of the households with plague had rodents found within their surroundings. Sixty eight percent of households reported that rodents increase after harvesting and 62.2% reported flea increase during the rainy season. Seventy one percent of the households had a human dwelling of less than or equal to 20 meters from where rodents with plague were found. On the other hand fleas were reported to be on the increase during

Table 1. Human attributes of the sampling information.

Variable	Category	n (%)
Reported human cases of plague, N=45	Yes	19 (42.2)
	No	26 (57.8)
Age of plague cases	Mean (SD)	10.86 (6.7)
Surrounding area of home, N=45	Clean	16 (35.6)
	Dirty	29 (64.4)
Bush/plain activities cases were involved in, N=76	Cattle herding and collection of firewood	58 (76.3)
	Other activities	18 (23.7)

**Figure 1.** Sex of plague cases number**Table 2.** Rodent attributes of the sampling information.

Variable	Category	n (%)
Nearest human dwelling where rodent was found	> 20 m	10 (22.2)
	≤ 20 m	32 (71.1)
Rodents with plague found in the surrounding, N=45	Yes	37 (82.2)
	No	68 (17.8)
Rodents specie which tested positive for plaue, N=45	<i>Gerbillurus</i>	41(91.1)
	Other (<i>rattus/mastomys</i>)	4 (8.9)
Reported time of year when rodent increase, N=41	Rainy season	10 (22.2)
	After harvesting	31 (68.9)
Reported time of year when rodent decrease, N=39	Cold season	12 (26.7)
	Rainy season	27 (60.0)

rainy season while they are reported to reduce during cold season (Table 3). Table 4 shows that eighty two

percent of the housing units were made of mud and more than half of these units were not plastered (57.8%). 80%

Table 3. Flea attributes of the sampling information.

Variable	Category	n (%)
Reported time of year when fleas increase, N=41	After harvesting	13 (28.9)
	Rainy season	28 (62.2)
Reported time of year when fleas decrease, N=39	Cold season	29 (64.4)
	Rainy season	10 (22.2)

Table 4. Characteristics of housing units in the households sampled.

Variable	Category	n (%)
Type of housing, N=45	Brick	8 (17.8)
	Mud	37 (82.2)
Type of wall, N=45	Plastered	19 (42.2)
	Not plastered	26 (57.8)
Type of floor, N=45	Concrete	9 (20.0)
	Temporal	36 (80.0)

of these units had temporal (not concrete) floor as compared to 20% which had permanent (concrete) floor. Almost all these households grew corn near their homes.

Households reporting cases compared with those who did not report cases exhibited no significant differences in activities such as cattle herding, firewood collection and other bush activities, $P > 0.05$ (Table 5). Households reporting plague cases were significantly more likely to have had rodents with plague found in their surrounding (94.7% vs 73.1%, $P=0.014$). Those households with a dirty surrounding (84.2% vs 50%, $P = 0.018$), with a radius of greater than or equal to 20 m as nearest human dwelling (94.7% vs 53.8%, $P = 0.013$) and those with walls which were not plastered (84.2% vs 38.5%, $P = 0.002$) were also significantly more likely to report human plague cases. According to information obtained from the medical offices in Namwala district, the disease is on the increase from February, March up to May. And when there are suspected cases, bubos are checked for human cases by taking specimens from the swelling. Confirmed cases are isolated and the maximum number of days of admission is 7 days with Doxycycline given once every 7 days for prophylaxis, with chloramphenicol and gentamicin being used for treatment.

DISCUSSION

Factors associated with plague in endemic areas of the disease in Zambia have not been studied extensively. In this study, 42.3% of the households had reported b

a human plague case. The mean age of the cases was 10.9 years showing that the disease affect mostly young children. This is supported by a study done in Zimbabwe which indicated that plague was associated with an age of 10 years or older (Manungo et al., 1998). The larger proportion affected by this disease are male children probably because most male children are more adventurous and may be linked to the hunting, killing and touching of the rodents and may be involved in many other outdoor activities. More than half of these households had dirty surroundings while most of them were made of mud and not plastered. Interestingly, member's involvement in bush activities, type of housing and floor were not associated with plague cases. This is in line with a study done in New Mexico which indicated that plague was as a result of entry of the reservoir host into the habitat of human rather than from entry of human into the sylvatic habitat of the reservoir host (Jonathan et al., 1979). Coming to control and treatment measures known by people, most of them reported using cats for control of rodents and taking patients to health center for treatment.

Human plague cases were associated with rodents with plague found in the surrounding area, and within a human dwelling of less than or equal to 20 m. A dirty surrounding area within the household and unplastered houses were also associated with plague cases. This could be as a result of rodents hiding in the dirty surrounding and themselves being infected with plague. The wall which is not plastered could also be the hiding area for fleas which can easily infect the humans. Eventhough

Table 5. Risk factors associated with reported cases of human plague.

Variable	Household reported a case (n=19)	Household did not report a case (n=26)	P -value
Rodents with plague found in surrounding area	18 (94.7)	19 (73.1)	0.014
Surrounding area of home dirty	16 (84.2)	13 (50.0)	0.018
Cattle herding and collection of firewood as bush activities cases were involved in	12 (63.1)	17 (65.4)	0.703
≤ 20 m as nearest human dwelling where rodents were found	18 (94.7)	14 (53.8)	0.013
Type of housing being mud	17 (89.5)	20 (76.9)	0.435
Type of wall, not plastered	16 (84.2)	10 (38.5)	0.002
Type of floor, temporal	16 (84.2)	20 (76.9)	0.712

the rodents were reported to increase in the surrounding areas of households after harvesting, the fleas were interestingly reported to increase in the rainy season. It is also during the rainy season that cases are reported to be on the increase. The reason could be that during the rainy season rodent barrels are flooded, resulting to rodents dying. The fleas which were on these rodents go to humans as the next hosts especially in the plains, to cause plague. This is in contrast to the study done in Vietnam where the incidence of plague is at its peak during the dry season (Pharm et al., 2009). This Vietnam study further reported that the risk of plague occurrence was associated with an increased monthly flea index and increased rodent density (Pharm et al., 2009). This agrees with the finding of our current study which indicates that when there is flea increase there is also plague increase in the rain season.

Maize (corn) was grown nearly in almost each and every household sampled. According to a study done in West Nile region of Uganda, they were able to identify potential residence-based risk factors for plague associated with huts within historic case or control villages (for example, distance to neighboring homestead and presence of pigs near the home) and huts within areas previously predicted as elevated risk or low risk (for example, corn and other annual crops grown near the home, water storage in the home, and processed commercial foods stored in the home) (MacMillan et al., 2010). To effectively control the transmission of plague we suggest that disease control measures which have been suggested be employed in these endemic areas. These control methods which have been suggested and used in disease management include preventive measures such as rat proofing buildings and also use of insecticide and repellents. Control of contact with patients and their immediate environment has also been suggested and used.

CONCLUSION

The entry of infected rodents with fleas to the human

habitat and the contact of fleas with humans contribute to the outbreak of plague especially under conditions which favour the survivor of fleas like unplastered houses, dirty surroundings and the existence of infected rodents within a household surrounding of 20 m or less.

RECOMMENDATIONS

Based on the results the following recommendations are made.

1. To effectively control the transmission of plague it is suggested that disease control measures such as use of insecticide to eliminate the fleas should be implemented in endemic areas.
2. People should be encouraged to plaster the houses whether brick or mud. They should also be encouraged to keep surrounding areas of the homes clean for a radius of 20 or more meters to keep away the bush rats.

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Conflict of Interests

The author(s) have not declared any conflict of interests.

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