

## Poor Housing Quality Increases Risk of Rodent Infestation and Lassa Fever in Refugee Camps of Sierra Leone

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**Abstract.** Lassa fever, a viral hemorrhagic fever endemic in parts of West Africa, is a severe febrile illness transmitted to humans by the rodent *Mastomys natalensis*. To determine risk of Lassa fever in households in Sierra Leonean refugee camps, we analyzed the spatial relationships between households with a Lassa case and focal locations of potential rodent habitats. Quality and hygiene factors of households were assessed to determine possible risk factors for household rodent infestation and occurrence of Lassa fever. The odds to have a rat burrow were higher in case houses than in control houses (OR 24, 95% CI 6.0–93). Case houses scored significantly worse in the quality of housing and external hygiene. These findings suggest that risk of Lassa fever in refugee camps depends on individual housing quality and the hygiene of the immediate surrounding environment.

### INTRODUCTION

Lassa fever is a viral hemorrhagic fever found predominantly in West Africa and is a significant cause of morbidity and mortality in Sierra Leone.<sup>1–4</sup> Primary infection with Lassa virus occurs through contact with the reservoir species, the multimammate rat (*Mastomys natalensis* Smith, 1834),<sup>3,5–7</sup> a rodent that is common throughout Africa. Secondary human-to-human transmission occurs through direct contact with a symptomatic Lassa case, infected body fluids, or remains.<sup>8,9</sup> Nosocomial Lassa outbreaks have been documented repeatedly.<sup>10–12</sup>

*M. natalensis* often lives near field crops and stored food and is frequently resident around human settlements. Infected *M. natalensis* harbors Lassa virus in blood and tissues and excretes the virus in its urine<sup>7,13</sup>; contact with contaminated fomites or foods may result in infection in individuals with skin abrasions, cuts, and scratches.<sup>14</sup> Risk factors for Lassa infection include hunting, cooking and eating rats, and having one's house infested by rodents.<sup>8,14</sup> In a study in the eastern province of Sierra Leone, *Mastomys* spp. comprised 50–60% of rodents captured in houses and 10–20% captured in surrounding agricultural and bush areas, suggesting that houses could be an important location for transmission of Lassa virus.<sup>8</sup> Capture/recapture studies have shown that *M. natalensis* does not move far from houses where they have established residence, averaging radial distances of 22 m in home range size.<sup>8</sup> However, individual rodents can move much greater distances (> 500 m) in search of food and shelter during seasonal population expansions or migrations and may change their residence several times over their lifespan.<sup>15</sup> Houses with a high proportion of virus-infected *M. natalensis* were shown to be associated with increased rates of infection in humans.<sup>8</sup> Houses offering a supply of water, food, and shelter afford an ideal environment for rodents, where they can deposit virus-laden urine on surfaces, such as eating utensils, beds, floors, and tables.<sup>9</sup>

Currently there is no vaccine against Lassa fever. The prin-

cipal strategies for preventing primary cases of Lassa fever are through surveillance and vector control. These strategies could be enhanced if areas and households at high risk of infection could be identified quickly and easily. We therefore studied whether readily-assessable household characteristics—like presence of rat burrows in external walls, housing quality, and hygiene of the house's immediate surroundings (external hygiene)—are associated with occurrence of Lassa fever in the household. We hypothesized that presence of rodent burrows could be a proxy for rodent infestation of the house and therefore be associated with occurrence of Lassa fever. Poor external hygiene could also be a risk factor for rodent infestation of the house or be an independent risk factor for occurrence of Lassa fever by providing opportunities for transmission outside the house. Poor housing quality could either be a risk factor of rodent infestation or be associated with Lassa fever through another pathway; it could, for instance, act as a socioeconomic proxy for food hygiene within the house.

We furthermore analyzed the spatial relationships between households where Lassa fever had occurred and focal locations that provide food, shelter, and water, such as latrines and waste collection points, as proximity and abundance of these focal locations could influence vector population dynamics and occurrence of Lassa fever.

### MATERIALS AND METHODS

**Study sites and population.** The study was conducted in 8 camps inhabited by Liberian refugees (Table 1). These camps are located in the central to eastern regions of Sierra Leone where Lassa virus is endemic. The refugees' country of origin, Liberia, is itself considered endemic for Lassa virus, but no recent epidemiologic data are available. The camps have between 5,000 and 9,000 inhabitants and are divided into geographic units called "phases" and further subdivided into "communities" consisting of ≈10–20 households; most camps have > 100 communities. Up to 10 refugees may inhabit a house, and they were usually responsible for its construction and maintenance. Because access to building materials and money are limited, housing quality and overall hygiene are relatively poor. Subsistence farming remains the main economic activity within the camps. Camp residents were encouraged to store food inside the house in rodent-safe containers

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TABLE 1

Distribution of refugee camp populations, the number of probable Lassa fever patients recorded (September 2002–July 2004), and number of control houses drawn from each camp

Camp	Population	Probable cases	Controls
Jimmi Bagbo	5,615	58	51
Largo	7,056	17	13
Gerihun	5,780	9	36
Taiama	5,813	4	17
Bandajuma	4,618	2	5
Total	28,882	90	122

that were to be raised off the ground; however, such containers were not always readily available. No outside granaries were used in the camps.

Houses were generally made of mud applied to wooden frameworks with reed or palm frond thatched roofs; their area was typically 5 × 6 m. Camps had simple pit latrines whose distribution varied by camp. Camps such as Largo had several latrines interspersed in each individual community, while other camps such as Jimmi Bagbo had clusters of latrines placed a short distance away from communities.

Individual camp health posts provide a basic level of health care and are responsible for disease surveillance within the camps. When clinics are unable to treat patients, they are referred to regional health centers or the Kenema Government Hospital (KGH) in the city of Kenema. This is the only hospital in Sierra Leone with a ward designated to treat Lassa patients, and most Lassa cases are transferred to KGH. Patients who correspond to the case definition (Box 1) are admitted to the Lassa ward and treated with intravenous ribavirin, a broad-spectrum antiviral. KGH does not have the laboratory capacity to confirm Lassa infection.

**Data collection.** Patient information was extracted from KGH medical records. All probable Lassa patients from the refugee population admitted to KGH’s Lassa ward between September 2002 and July 2004 were eligible for enrollment in the study. Patients’ houses were located in their respective camps by 3 teams of Merlin outreach workers, and geographic coordinates for each house were recorded using a global positioning system (GPS) unit. A household was regarded as a case household if at least one case of Lassa fever had occurred among permanent household members. Control households were recruited at random from the same camp’s population of households without Lassa cases. We did not recruit control households exclusively from the same community in which the case household was located in order to avoid overmatching for community characteristics. Their locations were similarly documented. GPS coordinates for all latrines and areas of refuse collection were recorded. However, in Gerihun camp, only latrine locations were recorded because waste was collected in bins and incinerated each week.

The condition of all case and control houses and their external hygiene were graded by one of the authors (P.C.B.) on the basis of the predefined criteria described in Box 2; these criteria are meant to reflect the rodents’ ease of access to the interior of the house and the rodents’ living conditions in the house’s surroundings. The presence of active rodent burrows in the house walls as evidenced by rodent footprints, scratch marks, or trails to the burrow was noted; holes in the house that did not show these characteristics did not qualify as evidence for rodent infestation. When houses were located but found destroyed, only the geographic coordinates were recorded. Food storage practices were not assessed, as we often did not have access to the interior of the households.

Data were transferred from the GPS handheld to a computer containing GARMIN MapSource software.<sup>9</sup> The data were then checked for completeness and plausibility.

Box 1

WHO case definition of Lassa fever employed in Kenema Government Hospital for diagnosis and treatment of patients where laboratory confirmation is not possible<sup>22\*</sup>

A patient with fever > 38°C not responding to effective antimalarial and broad-spectrum antibiotics, with no obvious localizing signs of infection and at least 2 major or 1 major and at least 2 minor criteria, is regarded as a probable case of Lassa fever.

**Major criteria**

- Abnormal bleeding (including hemoptysis, epistaxis, hematochezia hematemesis, or metrorrhagia)
- Swollen neck or face
- Conjunctivitis or subconjunctival hemorrhage
- Spontaneous abortion
- Unexplained tinnitus or altered hearing during a febrile illness
- Persistent low systolic blood pressure
- Known exposure to a confirmed Lassa patient
- Markedly elevated SGOT/AST

**Minor criteria**

- Headache
- Sore throat
- Persistent vomiting
- Diffuse abdominal pain/tenderness
- Retrosternal pain
- Diarrhea
- Generalized myalgia and arthralgia
- Profuse weakness
- Proteinuria
- White Blood Count < 4000 μL

\* The clinical combination of fever, exudative pharyngitis, retrosternal pain, and proteinuria distinguished Lassa fever from other febrile illness with a positive predictive value of 80% (see Ref. 22).

## Box 2

Housing quality and external hygiene scores used to categorize Lassa case and control households drawn from 8 refugee camps in Sierra Leone

### 1. Housing quality score

**Very Poor**—Building material is made of crumbling mud. Many holes are present. Inside of house is easily visible from outside. No protection for windows. Open space in roof. No foundation, house built directly on ground.

**Poor**—Building material is mud. Few holes are present. Inside of house is not easily visible. Windows are protected but inadequate. Roof is in moderate condition, some work needs to be done. Foundation is present but in poor condition.

**Satisfactory**—Building material is made of wood and mud and minor holes are present. Windows are protected. Roof is well-maintained, but minor holes are present. Foundation is good.

**Good**—Building material is made of concrete or solid mud and wood. Windows are tightly protected. Roof is well-maintained and tightly protecting. No holes are visible. Foundation is solid and in good condition.

### 2. External hygiene score

**Very poor**—Extensive vegetation and rubbish/clutter directly against the house. Vegetation is overgrown and probably found growing in base/foundation of house.

**Poor**—Vegetation and/or rubbish/clutter present but directly against the walls of the house.

**Satisfactory**—No debris, but vegetation and not against the house, or some debris but no vegetation but within 10 feet of house.

**Good**—No debris/clutter against or within 20 feet of the house.

**Analysis.** Within Arcview's Geo-processing extension, straight-line distances from houses to the nearest latrine and waste areas were calculated. The two-sample Wilcoxon rank-sum test was used to examine any difference in median distances to latrines and waste points between case and control houses. The  $\chi^2$  test and the score test for trend of odds were used in the bivariable analysis to investigate the association of case and control status with exposure to different environmental household characteristics. Because few houses had good external hygiene ( $N = 7$ ) and housing quality ( $N = 3$ ), the categories "good" and "satisfactory" were collapsed for the bivariable analysis. The multivariable analysis of risk factor for Lassa infection was performed using logistic regression. For the final model, the housing quality and external hygiene scores were further collapsed into two categories (good/satisfactory versus poor/very poor). We explored the

validity of identified risk factors as screening tools by estimating sensitivity and specificity.

Ethical clearance for this study was granted by the Sierra Leone Ministry of Health's ethics committee, the London School of Hygiene and Tropical Medicine's ethics committee, and the United Nations High Commissioner for Refugees (UNHCR) country health director. Participation in this survey was entirely voluntary, and participants could withdraw from the study at any time.

## RESULTS

A review of KGH Lassa ward records found 90 probable cases originating from the refugee camps between September 2002 and July 2004, including eight deaths (8.8% mortality).

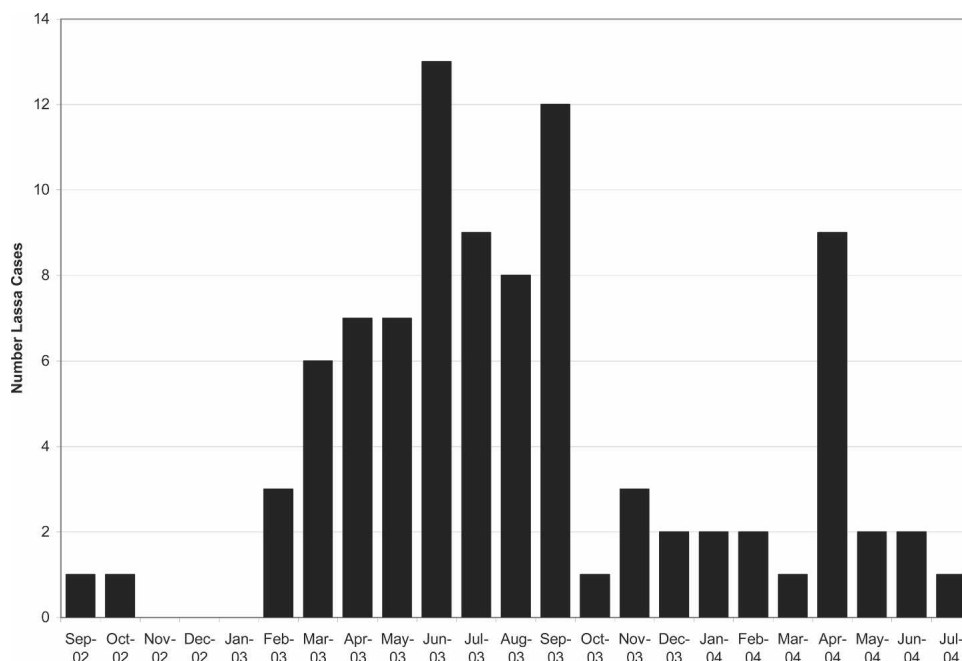


FIGURE 1. Cases of Lassa fever reported by month from KGH, September 2002–July 2004.

TABLE 2  
Lassa fever attack risk by age and sex from refugee camp residents in Sierra Leone, September 2002–July 2004

Age (years)	Patients			Attack risk, per 1000		
	Male	Female	Total	Male (95% CI)	Female (95% CI)	Total (95% CI)
0–4	4	7	11	1.5% (0.6–3.9)	2.7% (1.3–5.6)	2.1% (1.2–3.8)
5–17	10	12	22	1.8% (1.0–3.3)	2.3% (1.3–4.0)	2.1% (1.3–3.1)
18–59	24	31	55	4.3% (2.9–6.4)	5.1% (3.6–7.2)	4.7% (3.6–6.1)
60+	1	1	2	1.9% (0.3–10.7)	1.7% (0.3–9.6)	1.8% (0.5–6.5)
Total	51	39	90	2.4% (1.8–3.2)	3.5% (2.6–4.8)	3.1% (2.5–3.8)

Five of the eight camps reported cases of Lassa fever to KGH with the majority coming from Jimmi Bagbo camp. The numbers of cases were highest during the summer months and peaked in June 2003 (Figure 1). Incidence risk of Lassa fever was somewhat higher in females than males (3.5% versus 2.4%;  $P = 0.09$ ), and more than two times higher in the economically active age group 18–59 years (4.7%) than in the younger age groups of 0–4 years (2.1%;  $P = 0.02$ ) and 5–17 years (2.0%;  $P < 0.001$ ) or > 59 years (1.8%;  $P = 0.25$ ) age groups (Table 2). Geographic clustering of case households was detected using the spatial scan statistic<sup>16</sup> (P. C. Bonner, unpublished data), and 6 households were found with 2 cases each.

In bivariable analysis, we found the presence of rat burrows, housing quality, and external hygiene, but not distance to the nearest waste collection point and latrine to be associated with the occurrence of Lassa fever in a household (Table 3). The odds to have a rat burrow were much higher in case than in control houses (OR 24, 95% CI 6.0–93). Case houses scored significantly worse in the quality of housing and external hygiene. The odds ratios (ORs) for the categories “poor” and “very poor” of the external hygiene and housing quality scores were very similar. Dichotomizing the scores as good/satisfactory versus poor/very poor resulted in an OR of 2.2 (1.2–3.9) for housing quality and 5.4 (2.7–11) for external hygiene. The distance to the nearest waste collection point and to latrines was not significantly different between case and control households.

We also found housing quality and external hygiene to be associated with the presence of rodent burrows, with odds for presence of rodent burrows decreasing linearly with housing quality and external hygiene (Table 4).

The result of the multivariable logistic regression is shown in Table 5. For simplicity, we used the dichotomized scores of housing quality and external hygiene as outlined above. After adjusting for the presence of rat burrows, overall housing quality was no longer associated with occurrence of Lassa fever, but poor/very poor external hygiene remained an independent risk factor. The model including rat burrows, housing quality, and external hygiene confirms that presence of a rat burrow and poor external hygiene independently increase the odds of disease. In contrast, the risk of disease due to poor housing quality seems to be explained primarily by the presence of rat burrows.

We found the presence of rodent burrows to be an indicator of very good sensitivity (96%) for identification of risk households for Lassa fever (Table 6), followed by poor/very poor external hygiene (81%). The specificity of the evaluated indicators was rather modest, between 47% and 60%. By combining indicators, specificity could be increased to between 71% and 80%, at the expense of sensitivity. The most attractive 2-indicator combination was the one of rodent burrows and poor/very poor external hygiene, with a sensitivity of 79% and a specificity of 71%. Combinations without rodent burrows had a sensitivity of 60% or below.

TABLE 3

Association between occurrence of Lassa fever in a household and presence of rodent burrows, external hygiene, housing quality, and distance to latrines/waste collection points

	Case houses ( <i>n</i> = 84)	Control houses ( <i>n</i> = 122)	Odds ratio	95% CI	<i>P</i> value
Rodent burrow present					
No, <i>n</i> (%)	3 (4)	57 (47)	1.0		
Yes, <i>n</i> (%)	81 (96)	65 (53)	23.7	6.0–92.9	< 0.001*
External hygiene score					
Good/satisfactory, <i>n</i> (%)	16 (19)	68 (56)	1.0	–	< 0.001†
Poor, <i>n</i> (%)	49 (58)	41 (34)	5.1	2.4–10.6	
Very poor, <i>n</i> (%)	19 (23)	13 (11)	6.2	2.3–16.4	
Housing quality score					
Good/satisfactory, <i>n</i> (%)	34 (40)	73 (60)	1.0	–	0.007‡
Poor, <i>n</i> (%)	39 (46)	39 (32)	2.1	1.2–4.0	
Very poor, <i>n</i> (%)	11 (13)	10 (8)	2.4	0.9–6.2	
Median distance to waste collection points, in meters (range and quartiles)	53 (8-37-89-161)	43 (14-33-74-195)	–	–	0.28‡
Median distance to latrines, in meters (range and quartiles)	47 (5-25-97-331)	39 (3-22-89-438)	–	–	0.55‡

\*  $\chi^2$  test.

† Score test for trend of odds.

‡ Wilcoxon rank-sum test.

TABLE 4  
Association between presence of rodent burrows and external hygiene or housing quality

	Rodent burrow		Odds ratio	95% CI	P value
	Present (n = 146)	Absent (n = 60)			
External hygiene score					
Good/satisfactory (ref), n (%)	45 (31)	39 (65)	1.0	–	< 0.001*
Poor, n (%)	73 (50)	17 (28)	3.7	1.8–7.6	
Very poor, n (%)	28 (19)	4 (7)	6.1	1.8–20.1	
Housing quality score					< 0.001*
Good/satisfactory (ref), n (%)	60 (41)	47 (78)	1.0	–	
Poor, n (%)	67 (46)	11 (18)	4.8	2.2–10.5	
Very poor, n (%)	19 (13)	2 (3)	7.4	1.6–35.6	

\* Score test for trend of odds.

## DISCUSSION

This investigation was based on the hypothesis that readily assessable household characteristics—like the presence of rodent burrows, housing quality, and external hygiene—are associated with the occurrence of Lassa fever in the household and could be used as screening tools to identify Lassa-risk households. This study indicated that rodent burrows could be used as markers of a house's rodent infestation, with the presence of active rodent burrows strongly associated with occurrence Lassa fever in a household. Only about half of control houses in the refugee camp had visible rodent burrows, whereas almost all case houses had visible burrows. The absence of rodent burrows is a good indicator that the house is less likely to have a case of Lassa fever, and surveillance and rodent management programs may increase their cost-effectiveness by paying particular attention to houses with rodent burrows.

External hygiene (i.e. surroundings where rodents are provided with substantial opportunities to find food and shelter) was highly correlated with presence of rodent burrows and associated with odds of disease, even when adjusted for the presence of rat burrows and housing quality. Peridomestic *M. natalensis* is known to forage and migrate among village, agricultural, and grassland areas.<sup>17,18</sup> The refugee camps supplied ideal habitats for *M. natalensis*, providing a mosaic of agricultural and village areas. Also, specific areas in the human environment, such as heaps of firewood, shrubs, or rubble, are attractive to rodents for shelter and refuge.<sup>18</sup> Poor external hygiene may act as a risk factor for rodent infestation of the house and for transmission of Lassa virus in the house's immediate surroundings alike. This is in line with a study from Nigeria that reported a significantly higher seroprevalence for Lassa infection in inhabitants of villages with poor community

hygiene practices.<sup>19</sup> White<sup>20</sup> has shown that simple habitat manipulation is effective in preventing populations of rodents from reaching harmful densities. Our study also suggests that environmental changes, such as clearing rubble from around the houses and improving housing quality, may reduce the risk of Lassa fever.

The quality of the housing had no significant effect on the risk of disease once adjusted for presence of rat burrows. A survey from 2001<sup>21,22</sup> showed that unfit properties were more likely to have a rodent infestation than other properties, suggesting that the condition of the house affects the ability of rodents to enter and establish residence in a household. This finding is confirmed by the strong unadjusted association between housing quality and rat burrows in our study. In our view, the presence of rat burrows does not act as a confounder for the association between housing quality and occurrence of Lassa fever, but it does lie on the causal pathway between housing quality and the occurrence of Lassa fever, so improving housing quality may decrease rat infestation and the risk of disease alike.

Whether cleaning up the houses' surroundings and improving the quality of housing should be seen as a complement or as an alternative to trapping rodents remains to be investigated. In one study from Sierra Leone, trapping rodents did not reduce the seroconversion rate to Lassa virus in humans, but their trapping, as the authors concede, may not have been effective enough to have an effect on human infection.<sup>23</sup>

Given the severity of Lassa fever, its potential to cause epidemics, and the importance of early treatment and isolation of patients, indicators for Lassa-risk households should have a high sensitivity. "Presence of rodent burrows" fulfills this requirement unreservedly (96%). "Poor/very poor external hygiene" may have the advantage to be assessed more quickly, but this comes at the cost of missing more households

TABLE 5  
Association between occurrence of Lassa fever in a household and presence of rodent burrows, external hygiene, and housing quality: multivariable logistic regression (n = 84)

Risk factor	Multivariable analysis								
	Bivariable analysis			Adjusting for presence of rodent burrows only			Adjusting for all other factors		
	Crude odds ratio	95% CI	P value	Adjusted odds ratio*	95% CI	P value	Adjusted odds ratio†	95% CI	P value
Poor/very poor external hygiene	5.4	2.7–10.8	< 0.001	4.8	3.0–7.6	< 0.001	4.0	1.9–8.4	< 0.001
Poor/very poor housing quality	2.2	1.2–3.9	0.006	1.5	0.53–4.2	0.48	0.83	0.41–1.7	0.61
Rodent burrow present	23.7	6.0–92.9	< 0.001	–	–	–	19.6	5.6–68.6	< 0.001

\* Adjusted for presence of rodent burrows.

† Adjusted for the other two explanatory variables.

TABLE 6

Sensitivity and specificity of identified risk factors, and combinations thereof, as indicators for households with increased risk of Lassa fever occurrence

Indicator	Sensitivity (95% CI)	Specificity (95% CI)
Rodent burrow present	96% (90–99%)	47% (38–56%)
Poor/very poor external hygiene	81% (71–89%)	44% (35–54%)
Poor/very poor housing quality	60% (48–70%)	60% (51–69%)
Rodent burrow present and poor/very poor external hygiene	79% (68–87%)	71% (62–79%)
Rodent burrow present and poor/very poor housing quality	60% (48–70%)	70% (62–78%)
Poor/very poor external hygiene and poor/very poor housing quality	52% (41–63%)	75% (67–83%)
Rodent burrow present and poor/very poor external hygiene and poor/very poor housing quality	52% (41–63%)	80% (71–86%)

with a Lassa case (sensitivity 81%). The specificity of “Presence of rodent burrows” is quite low (47%), as is the specificity of the other indicators. If lack of specificity is deemed to be a logistical problem, then combining “Presence of rodent burrows” with “Poor/very poor external hygiene” would increase specificity to 71% but lower sensitivity to 79%. “Poor/very poor housing quality” compares unfavorably with the other 2 indicators in terms of sensitivity and specificity, and any combination of indicators without “Presence of rodent burrows” has an unacceptably low sensitivity. In summary, surveillance teams may wish to concentrate their efforts on houses with rodent burrows, particularly if their surroundings are untidy; they would still have to deal with a large proportion of false positives, but this screening would spare them considerable efforts compared with no screening.

Another hypothesis we examined was whether increasing proximity of latrines or waste disposal areas to households would increase the risk of Lassa fever. This hypothesis relies on the widely accepted view that commensal rodent numbers are higher near refuse sites where food, water, and shelter are in relative abundance. However, our analysis showed no association between the occurrence of Lassa fever in a household and the distance to human waste centers. This may be explained by the fact that distances from most houses to individual waste centers in camp communities were designed to be sufficiently close to houses for convenience and sanitation reasons, therefore putting most households within the known ranging behaviors of *M. natalensis*.

Because Sierra Leone is rehabilitating from a protracted civil war, conditions were unfavorable for research and contributed to a number of study limitations. An important limitation of this study is the absence of laboratory confirmation of Lassa antigen or antibody in our patients. At the time of this study, KGH did not have the resource capacity to confirm Lassa cases through standard laboratory tests or to send samples to reference laboratories. To reduce unnecessary treatment costs, undue exposure to ribavirin, and waste of intravenous ribavirin, KGH used the WHO clinical case definition (Box 1), which has been shown to significantly increase the specificity of clinical diagnoses.<sup>1,24</sup> On earlier occasions, 50–70% of diagnoses based on this case definition were confirmed by serology (D. Bausch, personal communication). The very strong association between presence of rodent burrows and occurrence of disease also suggests that most of these cases were indeed Lassa fever, as most other diseases that could have been mistaken for Lassa fever are not rodent-borne. If there are some false cases among our study participants, and risk factors were distributed randomly among

them, then the associations we found are likely to be underestimated. It is furthermore possible that cases of Lassa infection, particularly subclinical and mild ones, have been under-reported and were present in our control households; most Lassa infections are subclinical.<sup>25</sup> Such misclassification again would have led to underestimating the association between the risk factors we identified and clinical Lassa fever. As it is clinical Lassa fever that matters most for individual and public health, this is what our interest was focused on.

The time lag between occurrence of Lassa fever and assessment of housing quality, external hygiene, and presence of rat burrows was up to a year. The underlying assumption of our analysis is that housing quality, external hygiene, and rodent infestation had not changed much in between, but we have no means to prove this. For example, if a money earner had died due to Lassa, this may have led to neglecting house maintenance; this would be case for reverse causality, which is difficult to rule out in cross-sectional studies. Most patients, however, were still alive at the time of this study.

Grading of all case and control houses was conducted by one of the authors (P.C.B.). Because blinding of the case status of the households was not possible, this approach may have led to observer bias. We used detailed, predefined grading criteria to protect our results against this type of bias.

Also, as Sierra Leone is just beginning the rehabilitation process from conflict, Lassa fever control programs are absent or rudimentary with the notable exception of a few Lassa fever education programs run by NGOs in the refugee camps. Progress is being made as a Lassa fever diagnostic laboratory is currently being built at KGH to support the Lassa fever ward. It is hoped that future Lassa fever control programs will use our results as guidance for their activities in the way we suggested above.

In conclusion, this study shows that the risk of Lassa infection in refugee camps depends on individual housing quality and the hygiene of the immediate surrounding environment. Interventions aimed at making houses more resistant against rodent infiltration and at sanitizing the houses' surroundings may be effective to reduce the occurrence of Lassa fever; more research is needed, however, to demonstrate the cost-effectiveness of such interventions. Surveillance may become more efficient by concentrating efforts on, but not limiting efforts to, houses with rodent burrows.

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