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Animal livestock and the risk of hospitalized diarrhoea in children under 5 years in Vietnam

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Abstract

OBJECTIVE To investigate the association between environmental exposure to livestock and incidence of diarrhoea among Vietnamese children.

METHODS A population-based cohort of 353 525 individuals, living in 75 828 households in Khanh Hoa Province, Vietnam, with baseline data covering geo-referenced information on demography, socio-economic status and household animals was investigated. Geographic information system was applied to calculate the density of livestock. The data were linked to hospitalized diarrhoea cases of children under 5 years recorded at two hospitals treating patients from the area as inpatients in the study area.

RESULTS Overall, 3116 children with diarrhoea were hospitalized during the study period. The incidence of diarrhoea hospitalization was 60.8/1000 child-years. Male gender, age <2 years, higher number of household members and lack of tap water were significantly associated with an increased risk of diarrhoea. There was no evidence that ownership of livestock increased the risk of diarrhoea. In spatial analysis, we found no evidence that a high density of any animals was associated with an increased risk of diarrhoea.

CONCLUSIONS Exposure to animals near or in households does not seem to constitute a major risk for diarrhoea in children under the age of 5 in Vietnam. Public health interventions to reduce childhood diarrhoea burden should focus on well-recognized causes such as sanitation, personal hygiene, access to adequate clean water supply and vaccination.

keywords livestock, Vietnam, childhood, hospitalized, diarrhoea

Introduction

Diarrhoea is the second most common cause of hospitalization and death in children under 5 years worldwide, especially in low-income settings (Black *et al.* 2003; Bryce *et al.* 2005). Diarrhoea is caused by a wide range of bacterial (Zurawska-Olszewska *et al.* 2002; von Seidlein *et al.* 2006; Jafari *et al.* 2009), viral (Van Man *et al.* 2005; Ramani & Kang 2009) and protozoal organisms (Elliott 2007). Some of these can be found in livestock (Tran *et al.* 2004) and its products (Ha & Pham 2006) and are often carried by domestic flies (Echeverria *et al.* 1983).

In Vietnam, livestock plays an important economic role for many households. Despite rapid economic development in Vietnam, many children continue to frequently suffer from diarrhoeal diseases. Previous studies have often focused on water, sanitation and hygiene issues as risk factors for diarrhoea. The role of livestock in the transmission chain of diarrhoea pathogens is less well explored.

Salmonella and *Campylobacter* are frequently isolated from chicken faeces, chicken raw meat and organs (Ha & Pham 2006; Luu *et al.* 2006; Tran *et al.* 2006). Keeping poultry could contribute to transmission of diarrhoea pathogens by contaminating the environment via faeces to which children are easily exposed (Grados *et al.* 1988). Given high ambient temperatures, poor hygiene and insufficient food storage facilities, low-income settings in the tropics (should) provide ideal conditions for food contamination (Islam *et al.* 1993; Motarjemi *et al.* 1993; Lanata 2003).

Ruminants (e.g. cows and buffalos) and swine have been shown to contribute to the transmission of diarrhoea pathogens such as *Cryptosporidium parvum* and a range of Enterobacteriaceae (Germani *et al.* 1994). Recently, Ahmed *et al.* (2007) have detected rotavirus G5P[6] strain originated from swine in a child with clinical diarrhoea in Vietnam. A study from Israel found that exposure to livestock increased the odds of giardia infection by nearly five times (Coles *et al.* 2009). Presence of animal faeces in the compound was found to be associated with an increased risk of diarrhoea in children in Kenya (Shivoga & Moturi 2009). However, it has also been hypothesized that animal exposure may also lead to immunity, for example, against cryptosporidium, as shown in an outbreak report (Mayne *et al.* 2011).

Given that a large proportion of households in Vietnam own or raise livestock, we aimed to clarify whether this activity increases the risk of diarrhoea in this setting. We explored this question through the application of geographic information system technology and analysis in the context of a well-characterized study population in south central of Vietnam and the associated risk of diarrhoea incidence in children <5 years of age.

Materials and methods

Study population

The study area encompasses 33 communes in Nha Trang city and Ninh Hoa district of the south central, coastal province of Khanh Hoa in Vietnam. In mid-2006, a census was conducted in Nha Trang city and Ninh Hoa district as part of the Khanh Hoa Health Project (Yanai *et al.* 2007). Information on socio-demographic factors, occupation, house structure, hygiene, water source, household animals as well as admission to hospital for diarrhoea in the 12 months prior to the survey was collected. GPS data were collected using GPS receiver Magellan GPS-320 (Magellan Corporation, San Dimas, CA, USA) in 2003 (Ali *et al.* 2005a) and updated during this census for new households. We divided the study area into urban and rural according to government information.

Details of the study population have been published elsewhere (Suzuki *et al.* 2009). In brief, the census survey covered 75 828 households (Table 1). The study population in mid-2006 was 353 525 with 49.3% males. The percentage of children <5 years of age was 7.0% (n = 24 768). Main economic activities are tourism, agriculture and fishery. About half of the households had access to tap water. Latrine coverage was 66% (census 2002, unpublished data).

Two public tertiary care hospitals, Khanh Hoa General Hospital and Ninh Hoa District Hospital, were the only two hospitals in the study area that had inpatient facilities for the treatment of acute diarrhoea in the study area. Patient data were entered into a study database as codes, based on *International Classification of Diseases*, 10th

Table 1 Characteristics of the study population (n = 75 828)

Characteristics	n (%)
Household	
Composition of house	
Bricks	68 033 (89.7)
Mud bricks	2755 (3.6)
Wood	2282 (3.0)
Other	2758 (3.64)
Water source	
Tap	36 845 (48.6)
Well	33 582 (44.3)
Other	5401 (7.1)
Mean number of household members	4.7 (SD 2.1)
Wealth level	
Low	20 467 (27.0)
Middle	36 935 (48.7)
High	18 426 (24.3)
With children <5 years	20 604 (27.2)
Area	
Urban	29 624 (39.1)
Rural	46 204 (60.9)
Individual	
All	353 512 (100.0)
Age group	
0–4	24 768 (7.01)
5–9	28 888 (8.2)
10–17	63 584 (18.0)
18–59	206 962 (58.5)
60+	29 310 (8.3)
Female	179 375 (50.7)
Area	
Nha Trang (Urban)	198 721 (56.2)
Ninh Hoa (Rural)	154 791 (43.8)
Final education*	
No education	10 800 (4.6)
Primary school level	83 363 (35.3)
Secondary school level	78 985 (33.5)
High school and above level	62 770 (26.6)
Occupation*	
White collar	21 331 (9.0)
Worker	65 892 (27.9)
Farmer	55 597 (23.6)
Fishery	9496 (4.0)
Housewife	28 467 (12.1)
Other	34 924 (14.8)
Retired	8394 (3.6)
Unemployed	11 709 (5.0)
Ruminant (cow/buffalo)	
Yes	7837 (10.34)
No	67 991 (89.66)
Swine	
Yes	4793 (6.32)
No	71 035 (93.68)
Poultry (chicken/duck)	
Yes	23 996 (31.65)
No	51 832 (68.35)

Table 1 *(Continued)*

Characteristics	*n* (%)
Dog	
Yes	38 274 (50.47)
No	37 554 (49.53)
Cat	
Yes	12 614 (16.64)
No	63 214 (83.36)

*Participants aged >18 years.

edition (ICD-10) (codes), allowing linkage with the census data. The diarrhoea ICD-10 codes includes A00-A05, A09 and A80-A85 (Fischer *et al.* 2007). We included diarrhoea cases of children <5 years from the study area, admitted to the two hospitals, between January 2005 and December 2006 if they could be linked to the census.

Data management and analysis

Data were double entered and managed using the FoxPro 7.0 (Microsoft, USA). Hospitalized diarrhoea data were cleaned to eliminate duplicated admissions of the same diarrhoea episode using an interval of 5 days between two admissions (Baqui *et al.* 1991). The database was transferred to Stata 10.0 (Stata Corp., USA) for statistical analysis.

As we were primarily interested in the effect of animal proximity on diarrhoea in children, we restricted documentation of livestock to those reared within 50 m of a household. For crowding, we used housing space per person (m^2) as an index of crowding and regarded 12 m^2 as cut-off value, referencing a guideline for healthy housing for European countries (World Health Organization 1988). Wealth levels were constructed based on an asset index used previously to assess household socioeconomic status (Suzuki *et al.* 2009). Three wealth levels were defined as follows: lowest 25th percentile of the asset index was defined as 'Low', the 25th to 75th percentile as 'Middle' and the highest 25th percentile as 'High'.

Diarrhoea hospital admission rates were modelled in an open cohort using Poisson regression as children who were born between January 2005 and mid-2006 (the time of the census) were included in the cohort. We had no information on outmigration of the study population after the census, but considered the whole population at risk throughout the study period between January 2005 and December 2006. We used robust standard errors to account for within-household correlation and to adjust for clustering within 250-m grid cells (animal density analysis). Child-years of observation was stratified by age group (at 1, 2, 3 and 4 years) to account for ageing of the children. Child-years, hospitalized diarrhoea rate and animal density were calculated as Kernel density estimation using ESRI® ArcMap™ version 9.2 (The ESRI Inc., CA, USA) using a grid cell size 250 m. Hotspots were analysed using Getis-Ord Gi* hotspot analyses (using inverse-distance weighting), and Moran's I test was used to evaluate the spatial autocorrelation (clustering) for diarrhoeal incidence rate (Kelly-Hope *et al.* 2009).

Ethical approval for the project was obtained from the Institutional Review Board (IRB) of the National Institute of Hygiene and Epidemiology (NIHE), Vietnam, and the IRB of the Institute of Tropical Medicine, Nagasaki University, Nagasaki, Japan.

Results

During 51 241 child-years (cy) of observation under children 5 years old, there were 3116 diarrhoea episodes requiring hospital admission (60.8 per 1000 cy). Of these, 1811 diarrhoea cases (58.3%) could be linked to the census data. Figure 1 shows numbers of cases and linked cases over time. Distinct seasonal peaks of diarrhoea were detected during the mid-year dry, hot season and the 4th quarter cool, rainy season. There was no strong seasonal pattern observed among the children with diarrhoea during the study period.

Spatial analysis visually showed that diarrhoea incidence rates were lower in population dense area (Figure 2). It also identified multiple 'hot spot' areas with significant higher diarrhoea hospitalization rate, *Z*-score (≥1.96, $P < 0.05$) in the study area.

Hospitalized diarrhoea was less common in girls than in boys (Table 2). The rate was highest in children <1 year of age (77.51 per 1000 cy) and decreased by age. There was a trend towards diarrhoea being more common in households with larger number of occupants. The lack of access to tap water was significantly associated with an increased hospitalized diarrhoea. Hospitalized diarrhoea was significantly less common in urban areas than in rural areas. Crowding and parents' education level showed no major association with diarrhoea hospital admissions, but there was a trend towards fewer admissions with increasing distance to the nearest hospital (adjusted RR 0.65, 95% CI 0.50–0.84) (Table 2).

Of the households in the census area, 32% owned chicken or ducks/geese, 10% cows or buffalos, 6% swines, 50% dogs and 17% cats. Figure 2 illustrates the density of each animal in the study area. By comparing data on diarrhoea incidence rates with the distribution of domestic pets and animal livestock, we found no evidence that a high animal density area were associated

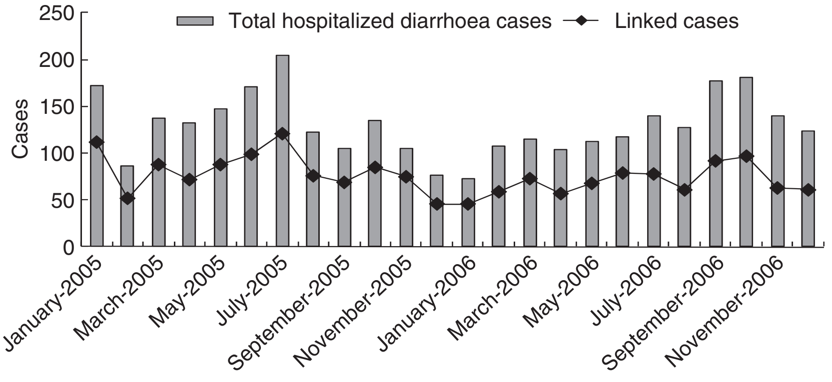

Figure 1 Distribution of hospitalized diarrhoea cases by months.

with higher rate of hospital admissions. Animal ownership in general was more common in rural than urban Khanh Hoa (65% *vs.* 28% for dogs, 46% *vs.* 3% for chicken, 10% *vs.* 1% for swine and 16% *vs.* 0.1% for cows). Excluding households with no animals, the mean number of animals per household was 4.6 (range 1–80) for swine, 4.7 (range 1–31) for buffalos, 1.5 (range 1–13) for dogs, 1.2 (range 1–61) for cats, 3.4 (range 1–80) for cows, 15.7 (range 1–7000) for chicken and 21.5 (1–6000) for ducks and geese. Livestock ownership was lower in households in the high-wealth category than in the low- and middle-wealth category (which owned similar numbers of the different animal types). Comparing low- and middle- with the high-wealth category, swine ownership was 7% *vs.* 3%, cow ownership 13% *vs.* 2%, chicken ownership 34% *vs.* 10%, duck/geese ownership 19% *vs.* 4%, and dog or cat ownership 36% *vs.* 25% (data not shown).

In univariate and multivariate analysis, children living in households with poultry, ruminants, swine, dogs or cats had no increased risk of diarrhoea hospital admissions (Table 3). We also found no evidence for a dose-response relationship; children in households in the upper quintile of animal density neighbourhood were at no significant higher risk of diarrhoea admission compared with children in the lowest quintile (Table 3).

Because of the strong association between tap water availability and diarrhoea (Table 2), we investigated the relationship between animal ownership and an increased risk of diarrhoea in households without tap water, where the risk of water contamination with pathogens may be greatest. We found no evidence for effect modification (interaction) based on the presence or absence of household tap water. There was no increased risk of diarrhoea associated with any type of animal in households without tap water: poultry, RR 0.96 (95% CI: 0.85–1.09); swines, RR 0.90 (95% CI: 0.72–1.11); ruminants, RR 1.15 (95% CI: 0.99–1.34); dogs, RR 1.10 (95% CI: 0.99–1.23); cats, RR 1.06 (95% CI: 0.93–1.22) (Table 3).

We further investigated an association between animal ownership and diarrhoea hospitalizations by analysing the study population separately for (i) rural areas and urban, (ii) diarrhoea incidence in 2005 and 2006, (iii) diarrhoea cases during the peaks and not during the peaks, and (iv) diarrhoea cases inside 'hot spot' areas. However, none of these factors was found to modify the lack of an association between animal ownership and diarrhoea.

Discussion

We found no evidence that children under the age of 5 years, living closely with livestock and other animals, have an increased rate of hospitalization with diarrhoea. Extensive subgroup analyses (e.g. water access, rural/urban, year, high-incidence/low-incidence periods) revealed no additional insights.

At population level, human-to-human transmission is likely to be the predominant mode of transmission. Animals may constitute an important source of diarrhoea pathogens, even if (as our data suggest) exposure to animals seems to pose few immediate risks in the directly exposed population of children. Zoonotic transmission from animals to humans (for example, of cryptosporidia) may occur, perhaps even frequently, causing subsequent human-to-human transmission. We cannot exclude that a separation of animals from humans may reduce zoonotic infections and epidemics in humans at a later stage.

Our findings do not eliminate the possibility that contamination of animal food products with enteric pathogens may contribute substantially to the burden of diarrhoea. The importance of adequate water supply was confirmed by our analysis, although we are unable to

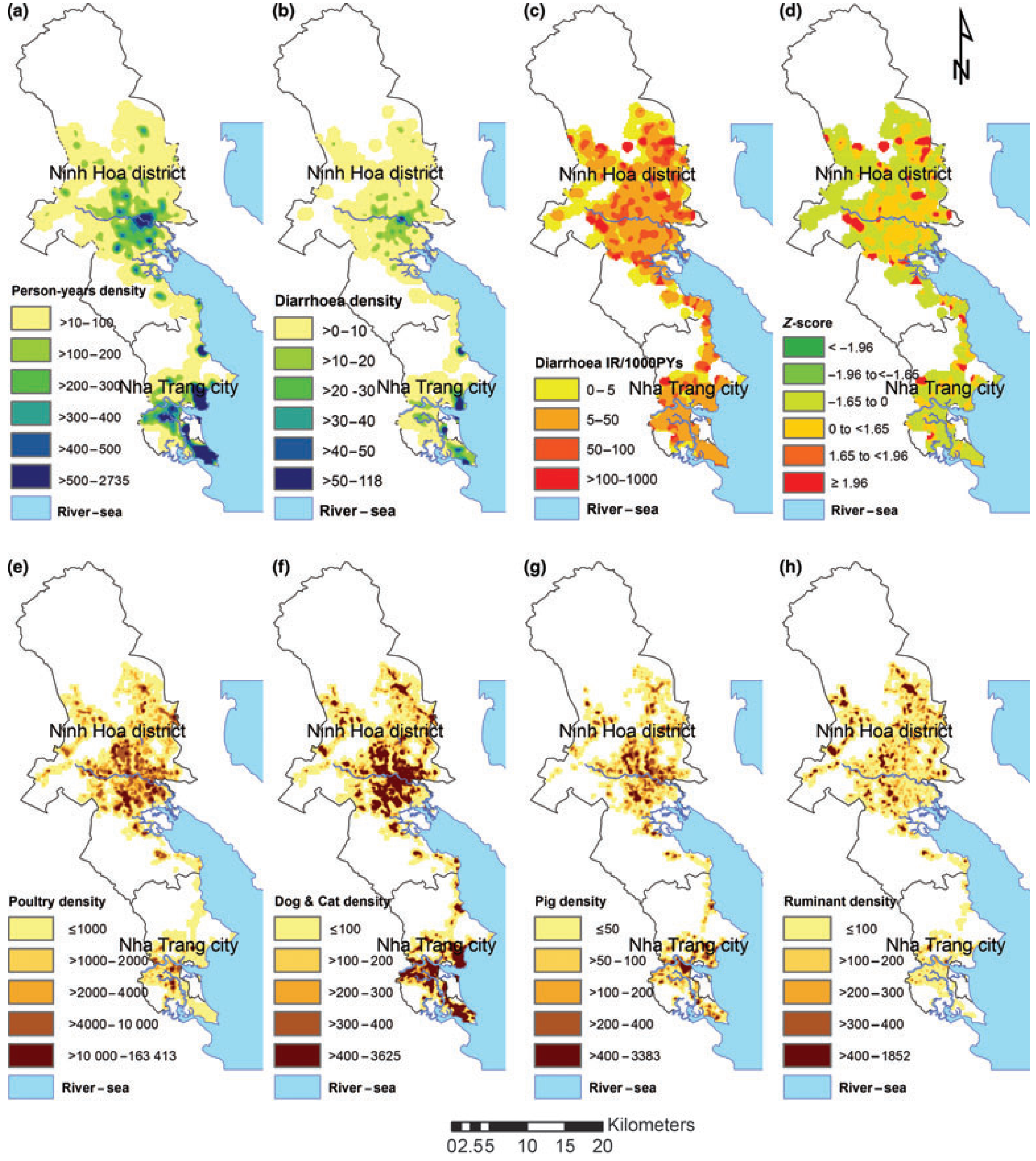

Figure 2 Population density (person-years/km^2) (a), diarrhoea density (episodes/km^2) (b), diarrhoea incidence rate (per 1000 Cy: child-years) (c), *Z*-score (Getis-Ord Gi*) (d) of diarrhoea in children <5 years and livestock densities per km^2 (e–h) in the study area based on 250-m grid cells.

Table 2 Univariate and multivariate analysis of risk factors for 1811 diarrhoeal episodes among 33 660 children <5 in 2005–2006

Characteristic	Rate/1000 cy (total cy)	Crude RR (95% CI)	Adjusted RR* (95% CI)
Overall rate of diarrhoea	35.34 (51 241.1)	–	–
Sex			
Male	41.88 (26 573.9)	1	1
Female	28.30 (24 667.2)	0.68 (0.61–0.75)‡	0.68 (0.61–0.75)‡
Age (months)			
0–11	77.51 (7728.1)	1	1
12–23	73.03 (10 050.6)	0.94 (0.85–1.05)	0.95 (0.85–1.06)
24–35	22.63 (11 134.3)	0.29 (0.25–0.34)‡	0.30 (0.25–0.34)‡
36–47	12.02 (10 982.0)	0.16 (0.13–0.19)‡	0.16 (0.13–0.19)‡
48–60	8.28 (11 346.0)	0.11 (0.09–0.13)‡	0.11 (0.09–0.13)‡
Number of family member			
0–4	29.90 (18 660.7)	1	1
5–6	36.14 (15 410.9)	1.21 (1.07–1.37)†	1.11 (0.98–1.26)
7+	40.54 (17 169.4)	1.36 (1.20–1.53)‡	1.16 (1.03–1.31)#
Composition of house			
Concrete, Brick	35.65 (45 475.3)	1	1
Non-brick	32.96 (5764.5)	0.92 (0.79–1.09)	1.04 (0.88–1.22)
Wealth level			
Low	30.37 (13 666.8)	0.84 (0.73–0.97)#	1.02 (0.75–1.04)
Middle	37.68 (25 079.4)	1.04 (0.92–1.18)	0.86 (0.73–1.02)
High	36.13 (12 481.2)	1	1
Water source			
Tap	32.65 (23 890.2)	1	1
Others	37.70 (27 350.9)	1.15 (1.05–1.28)†	1.21 (1.06–1.38)†
Water boiling			
Yes	34.60 (34 542.3)	1	1
No	36.85 (16 688.4)	1.07 (0.96–1.18)	1.11 (0.99–1.24)
Mother’s final educational level			
Primary school	31.91 (17 175.0)	0.87 (0.76–1.00)	1.01 (0.79–1.29)
Secondary school	37.69 (20 988.2)	1.03 (0.91–1.18)	1.01 (0.82–1.25)
High school and above	36.53 (10 622.7)	1	1
Father’s final educational level			
Primary school	29.98 (14 209.2)	0.84 (0.72–0.97)#	0.90 (0.68–1.20)
Secondary school	39.10 (18 005.7)	1.09 (0.95–1.25)	1.09 (0.86–1.38)
High school and above	35.83 (10 465.6)	1	1
Area			
Rural	36.72 (32 000.6)	1	1
Urban	33.06 (19 240.5)	0.90 (0.81–1.00)#	0.88 (0.76–1.01)
Distance to nearest hospital			
1–<5 km	35.61 (32 069.2)	1	1
5–<10 km	37.54 (15 476.0)	1.05 (0.95–1.17)	0.99 (0.88–1.11)
10–<25 km	24.18 (3639.5)	0.68 (0.53–0.86)†	0.65 (0.50–0.84)‡

Cy, child-years; RR, rate ratio; CI, confidence interval.
*All models were adjusted for wealth, highest father/mother education, distance to hospital, water source, urban, age and gender.
#$P < 0.05$. †$P < 0.01$. ‡$P < 0.001$.

determine whether the beneficial effect of tap water supply was attributed to improved water quantity, quality or both. As rotavirus is one of the major causes of childhood diarrhoea, introduction of rotavirus vaccine can be highly effective in reducing hospitalizations associated with rotavirus diarrhoea in children (Zaman *et al.* 2010; Anh *et al.* 2011).

Thus, control efforts could include addressing issues of food hygiene, sanitation, personal hygiene, access to adequate clean water supply and vaccination.

Our analysis may be limited by the potential of residual confounding in particular from socio-economic characteristics, access to health care and analysis limited to hospitalized cases. Children admitted to hospital are

Table 3 Univariate and multivariate analysis for 1811 diarrhoea episodes among 33 660 eligible subjects 2005–2006

Characteristic	Rate/1000PYs (total cy)	Crude RR (95% CI)	Adjusted RR* (95% CI)
Ruminant (cow/buffalo)			
Yes	39.80 (5903.9)	1.15 (0.99–1.33)	1.15 (0.99–1.34)
No	34.76 (45 337.2)	1	1
Swine			
Yes	34.95 (3175.8)	0.99 (0.80–1.22)	0.90 (0.72–1.11)
No	35.37 (48 065.3)	1	1
Poultry (chicken/duck)			
Yes	36.22 (16 425.4)	1.04 (0.93–1.15)	0.96 (0.85–1.09)
No	34.93 (34 815.7)	1	1
Dog			
Yes	37.82 (24 777.3)	1.15 (1.04–1.26)†	1.10 (0.99–1.23)
No	33.03 (26 463.8)	1	1
Cat			
Yes	39.00 (7973.7)	1.13 (0.99–1.28)	1.06 (0.93–1.22)
No	34.67 (43 267.4)	1	1
Poultry (chicken & duck) density quintile (mean poultry per km^2)			
1st quintile (59)	34.74 (9527.5)	1	1
2nd quintile (306)	36.47 (9925.8)	1.05 (0.89–1.24)	1.04 (0.87–1.24)
3rd quintile (1113)	29.97 (10 109.4)	0.86 (0.72–1.03)	0.82 (0.68–0.98)
4th quintile (3506)	38.28 (10 318.1)	1.10 (0.94–1.29)	0.99 (0.81–1.21)
5th quintile (13850)	34.74 (9527.5)	1.10 (0.93–1.29)	0.94 (0.78–1.15)
Dog and cat density quintile (mean dog/cats per km^2)			
1st quintile (217)	35.27 (10 605.2)	1	1
2nd quintile (514)	35.30 (10 284.6)	1.00 (0.86–1.17)	0.99 (0.85–1.15)
3rd quintile (815)	37.39 (10 296.0)	1.06 (0.90–1.25)	1.03 (0.88–1.22)
4th quintile (1238)	34.72 (9676.3)	0.98 (0.84–1.16)	1.00 (0.84–1.18)
5th quintile (2092)	34.99 (9546.6)	0.99 (0.84–1.18)	1.02 (0.84–1.22)
Swine density quintile (mean swine per km^2)			
1st quintile (3)	36.26 (10 343.0)	1	1
2nd quintile (50)	33.57 (9949.8)	0.93 (0.78–1.10)	0.89 (0.75–1.05)
3rd quintile (116)	34.68 (10 209.0)	0.96 (0.81–1.12)	0.90 (0.77–1.05)
4th quintile (217)	38.39 (9923.9)	1.06 (0.90–1.25)	0.98 (0.83–1.15)
5th quintile (646)	34.86 (9983.0)	0.96 (0.82–1.13)	0.88 (0.75–1.04)
Ruminant (cow and buffalo) density quintile (mean ruminants per km^2)			
1st quintile (0)	33.81 (17 364.4)	1	1
2nd quintile (1)	39.28 (1985.8)	1.05 (0.58–1.91)	1.07 (0.85–1.34)
3rd quintile (30)	34.92 (9967.1)	0.79 (0.51–1.20)	0.96 (0.80–1.15)
4th quintile (137)	36.51 (10 545.4)	0.92 (0.62–1.38)	0.97 (0.80–1.17)
5th quintile (489)	37.36 (10 546.1)	1.33 (0.92–1.93)	1.02 (0.84–1.25)
Total animal density quintile (mean animals per km^2)			
1st quintile (743)	33.37 (10 009.4)	1	1
2nd quintile (1687)	34.43 (9 788.2)	1.03 (0.87–1.23)	1.03 (0.86–1.22)
3rd quintile (2682)	36.59 (9920.9)	1.10 (0.92–1.30)	1.05 (0.89–1.24)
4th quintile (4763)	35.29 (10 143.4)	1.06 (0.89–1.26)	0.99 (0.83–1.18)
5th quintile (15474)	37.93 (10 546.9)	1.14 (0.96–1.34)	1.00 (0.84–1.20)

Cy, child-years; RR, rate ratio; CI, confidence interval.

*All models were adjusted for water source, wealth, parent's education (father or mother who had the higher education level), distance to hospital, urban, age and gender.

†$P \leqslant 0.01$.

more likely to have diarrhoea of greater severity. This does not need to be a weakness of this analysis because severe cases are those of highest public health interest. We found that education and wealth level were not strongly associated with diarrhoea. Higher use of health services in educated, wealthy individuals (usually at low risk of diarrhoea) may have masked an actually higher risk of diarrhoea in less-educated and less-wealthy families. Free health care for children under the age of 6 years has been introduced in the study area since October 2005, that is, for most of the study period, healthcare costs should not have been a barrier to healthcare seeking. We found that this fee exemption had little impact on actual admission rates.

We were not able to link 40% of cases to the census, possibly due to diarrhoea cases among the mobile sections of the population and newly born babies after the census, who were not part of the cohort. It seems unlikely that animal ownership is related to chance of a hospitalization being linked to the census data, which would introduce bias.

We found a strong relationship between hospitalized diarrhoea and distance to the nearest hospital. This might be a result of healthcare seeking behaviour, which was consistent with findings from another study conducted in Khanh Hoa in 2002 (Ali *et al.* 2005b). Analytically, it is not always easy to adjust for distance to the hospital. We used a simple straight line distance, ignoring actual travel distances. In a sensitivity analysis, we restricted the calculations to people living within 10 km of the hospitals, but found no material change in the results.

Another limitation could be that the animal data were collected in a cross-sectional survey but were later applied for the whole study period while animal numbers may be changing over time. In a sensitivity analysis, we restricted the calculations to the year 2006 when the census was carried out, and for which the animal data should be most accurate. The results were very similar to the analysis of all years. We used a kernel density method to calculate animal density. In a sensitivity analysis, we tried an alternative measure by counting the number of animals within a radius of 100 around each household. Using these measures instead did not greatly alter the results shown in Table 3.

Based on these data, we conclude that exposure to animals near or in households do not seem to constitute a major risk for diarrhoea in children under the age of 5. Our analysis provides indirect support for focusing control efforts on human-to-human transmission, for example, by improved water access, sanitation, hygiene (Cairncross *et al.* 2010) or vaccination against specific pathogens such as rotavirus.

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