Epidemiol. Infect. (2002), **129**, 65–71. © 2002 Cambridge University Press
DOI: 10.1017/S0950268802006817 Printed in the United Kingdom

Risk factors for pneumonia in infants and young children and the role of solid fuel for cooking: a case-control study

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(*Accepted 3 January 2002*)

SUMMARY

We evaluated the risk factors for childhood pneumonia with particular reference to indoor air-pollution associated with solid fuel use for cooking (e.g. coal, wood, dung), using a case-control study in a children's hospital in Calcutta. Cases were 127 children aged 2–35 months of either sex admitted with pneumonia and controls were 135 children attending their immunization clinic. Solid fuel use (odds ratio = 3·97, CI = 2·00–7·88), history of asthma in the child (OR = 5·49, CI = 2·37–12·74), poor economic status indicator (OR = 4·95, CI = 2·38 to 10·28), keeping large animals (OR = 6·03, CI = 1·13–32·27) were associated with high risk of pneumonia after adjusting for confounding (logistic regression analysis). Nearly 80% of people in India use such smoke producing fuel and the population attributable risk would be very high. This finding has important health policy implications. Furthermore, history of asthma is a useful prognostic indicator for early action for prevention of severe pneumonia.

INTRODUCTION

Acute respiratory infection (ARI) is the most frequent illness globally and a leading cause of death in developing countries mainly due to pneumonia in children under 5 [1]. Globally 4 million children under 5 (31% of all causes of mortality) die from acute lower respiratory infection (ALRI) [2]. Of the ALRI associated deaths, half a million are associated with measles and quarter of a million respectively are associated with pertussis and perinatal causes. The mortality due to pneumonia is 10–50 times higher in the developing world and is therefore amenable to substantial improvement. A sustainable solution to the problem of high numbers of deaths associated with ARI has to be found in the prevention of pneumonia [3]. However, epidemiological data on the risk factors for ARI in developing countries are limited [2].

Exposure to both outdoor and indoor air pollution has been suspected to increase the risk of ARI in many developing countries [4, 5]. However, nearly half of the world's households are estimated to cook daily with unprocessed solid fuels which are mainly biomass fuels and coal and are an important cause of indoor air pollution. The proportion is as high as 80% in India and China [5]. Therefore, even a small increase in the risk of pneumonia associated with the use of unprocessed solid fuel for cooking will be associated with a substantial level of population attributable risk. Biomass fuel use has been found to be associated with a high risk of ALRI [5]; the odds ratio for ALRI in four studies ranged from 2·2 to 4·8. On the other hand, a case management strategy of WHO has demonstrated [5] that a simple algorithm for health workers to treat ARI in the community reduced ARI-

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associated mortality by about 42 % (95 % CI 18–65 %) in developing countries.

In this study, we evaluated putative risk factors for acute lower respiratory tract infection including the use of unprocessed solid fuel for cooking in infants and young children among the urban poor using a hospital-based case-control study.

MATERIALS AND METHODS

The study was conducted in a large children's hospital in the city of Calcutta. Treatment here is provided free and it largely serves the urban and peri-urban poor. Both the cases and controls were recruited from this hospital.

Definition of cases

Children aged 2–35 months, of either sex, sufficiently ill enough to be admitted into the in-patient services of B. C. Roy Memorial Hospital for Children, Calcutta, with a clinical diagnosis of pneumonia or bronchiolitis, with or without associated wheeze were considered for inclusion as cases. After the clinical diagnosis of the admitting medical officer was supported by the paediatrician in charge and additionally checked by one of our team to confirm that the case fulfilled the WHO criteria for pneumonia [2], based on tachypnoea with or without lower chest constriction and/or stridor, the case was included in the study.

Definition of controls

Children attending the immunization clinic of this hospital in the same week of recruiting a case were considered for inclusion as controls. Before finally including a child in the immunization clinic as a control a trained health worker interviewed the parents and ascertained, given a similar illness in the child such as pneumonia or severe diarrhoea, whether they would have brought the child to this hospital for treatment or to a similar charitable hospital. If the answer was yes, they were considered for inclusion. The controls were stratum matched for age and recruited in two age strata, 2–11 months and 12–35 months.

The study design allows a case to become a control on a subsequent occasion and a control to become a case in the same way. This design feature obviates the need for the rare disease assumption for a case control study when determining a rate ratio. Cases and controls were recruited for a full year (December 1997 to November 1998). The weather in Calcutta is subtropical and, except for the cooler 3 months of December, January and February, the weather is warm to hot and humid.

Data analysis

A series of 2×2 tables were created to examine exposures of interest and case-control status. Odds ratios and 95 % confidence intervals were calculated by Cornfield's approximation, as described by Fleiss [6], and the role of exposures was evaluated. Stratified analysis using the Mantel–Haenszel procedure [7] was used to examine confounding. Finally, an unconditional logistic regression model was used for adjusted analysis. EPI INFO 6.0 was used for data entry, editing and for univariate analysis. Stata® version 5.0 was used for logistic regression models.

RESULTS

Exploratory univariate analysis identified a large number of putative risk factors or prognostic indicators for ALRI including pneumonia in infants and young children. Age groups (Table 1) were evenly balanced as expected from the study design. Significantly more boys were among the cases than controls as has been reported by others [2]. The proportion of children having two or more siblings was significantly higher among cases (OR 2·2, CI 1·13–4·35). However, the family size (defined as those who eat from the same cooking pot) and the proportion of families living in a one-room house were similar in the two groups. The proportion breast-fed was also similar in the two groups. Low weight for age (i.e. < -2 standard deviation score or Z score from the reference median based on National Center for Health Statistics data) was associated with a more than threefold increase in the risk of pneumonia (OR 3·26, CI 1·82–5·85) and so was low mid-arm circumference (OR 1·98, CI 1·17–3·36). Infants delivered at home had a 3·5-fold increased risk of pneumonia. All the adverse economic indicators (Table 2) were associated with an increased risk of pneumonia; low family income, not owning a TV or an electric fan or a home with non-cemented floor and wall were associated with 3, 8, 7 and 10-fold increased risk of pneumonia, respectively. Lack of education of the mother or the father (Table 2) was associated with a high risk of pneumonia, which also demonstrated a gradient

Table 1. *Factors associated with ARI: univariate analysis*

	Case (n = 127)	Control (n = 135)	Odds ratio (95% CI) P value
Age group			
2–11 m	92	99	
12–35 m	35	36	$P = 0·98$
Sex, boys (%)	64·6%	50·4%	1·80 (1·06–3·06)
Weight for age, % < -2 Z-score	44·9	20	3·26 (1·82–5·85)
Mean (S.D.) weight/age Z-score	−1·81 (1·083)	−1·149 (1·093)	$P = 0·000002$
Mid-arm circumference, cm median (quartiles)	12·5 (11·5 to 13·1)	13·0 (12·1 to 13·6)	$P = 0·006$
% < median (combined)	60·6	43·7	1·98 (1·17–3·36)
Number of sibs			
0	45%	52%	—*
1	30%	35%	1·03 (0·69–2·37)
⩾ 2	25%	13%	2·2 (1·13–4·35)
One room house (%)	62·3	62·7	1·07 (0·63–1·83)
Family size median (quartile)	5 (4–7)	5 (4–7)	$P = 1·0$
Child delivered at home (%)	43	17	3·62 (1·97–6·68)
Breast-fed	89%	87%	$P = 0·30$

* Reference category.

effect. At least some of these indicators, such as parental education are likely to operate through some proximate determinants, e.g. capability for achieving a better economic status, exercise of choice for a smaller family, use of a cleaner fuel and better health seeking behaviour.

Environmental factors

The important environmental factor of major interest was the use of solid fuel for cooking, an important cause of indoor air pollution (Table 3). Use of any of the three commonly used solid fuels for cooking, i.e. coal, wood or cowdung was associated with 2·7, 4·8 and 5·6-fold increased risk of pneumonia and use of any one or more of these types of solid fuel was associated with an eightfold increased risk of pneumonia. Keeping large animals like cattle, buffalo or goats for economic reasons, was associated with 14-fold increased risk of pneumonia. Keeping poultry and/or birds as pets was associated with threefold higher risk. Father's smoking was not shown to be associated with an increased risk. Only one mother gave a history of smoking. Living in a house with a mud-floor (an economic as well as a dampness indicator) was associated with a 10-fold increased risk of pneumonia.

Asthma

A history of wheeze or asthma-like illness in the child was associated with a sevenfold increased risk of pneumonia and a history of asthma in a sibling or parents was associated with a more than 2·6-fold higher risk (Table 3).

Adjusted analysis

Adjusted analysis using a logistic regression model was carried out to adjust for the confounding and evaluate the risk factor of major interest, i.e. use of polluting solid fuel for cooking as an indicator of

Table 2. *Association of economic indicators and parental education with ARI: univariate analysis*

Factors	Case (n = 127)	Control (n = 135)	Odds ratio (95% CI)
Economic indicators			
Low family income (% with < median income)	72·4	46·7	3·00 (1·73–0·23)
Owns TV (%)	15	60	0·12 (0·06–0·22)
Owns electric fan (%)	49	87	0·14 (0·07–0·27)
Home with cement floor and wall (%)	34·6	83·7	0·10 (0·05–0·19)
Education			
Mother's schooling			
Illiterate	48	22	—*
1–5 years	36	29	0·57 (0·26–12·19)
6–10 years	39	62	0·29 (0·14–0·57)
> 10 years	4	22	0·08 (0·02–0·29)
Father's schooling			
Illiterate	30	13	—*
1–5 years	34	22	0·67 (0·26–1·69)
6–10 years	55	63	0·38 (0·17–0·85)
> 10 years	8	37	0·09 (0·03–0·28)

* Reference category.

indoor air pollution (Table 4). A large number of variables were adjusted for, which included indicators for economic status, nutrition of the child, number of siblings (as an indicator of crowding of the immediate environment of the child), mother's education at four levels, a history of one or more asthma-like illness attacks in the child, and keeping animals or birds at home. The economic indicators were closely related. Therefore, a composite economic status indicator was created by combining four economic factors. The economic factors used and their values were as follows: owns TV (Yes = 1, No = 0); owns electric fan (Yes = 1, No = 0); lives in a house with cement floor and wall (Yes = 1, No = 0); income > median (Yes = 1, No = 0). After adjustment, use of solid fuel for cooking was associated with a fourfold increased risk of pneumonia (OR 3·97, CI 2·00–7·88) in infants and young children. History of asthma remained an independent risk factor after adjustment and was associated with a more than fivefold increased risk of pneumonia (OR 5·49, CI 2·37–12·74). Poor economic status was associated with a nearly fivefold increased risk (OR 4·95, CI 2·38–10·28) of pneumonia. Keeping animals (cow/buffalo/goat) remained a risk factor (OR 6·03, CI 1·13–32·27) while keeping birds was no longer a significant risk factor to pneumonia after adjustment (OR 1·15, CI 0·32–4·13).

DISCUSSION

Since acute respiratory infection (particularly pneumonia) is a leading cause of death in developing countries in children under 5, identifying risk factors for pneumonia which are potentially amenable to appropriate intervention is of public health importance. In this study among urban poor, several risk factors have been identified which may have implications for health intervention programmes.

An important finding of this study is the association between use of a smoke producing fuel for cooking and a high risk of pneumonia in infants and children. Conventional cooking stoves for solid fuel as used by

Table 3. *Association of environmental risk factors and history of asthma in the child, sibs and parents as ARI risk factors: univariate analysis*

	Case ($n = 127$)	Control ($n = 135$)	Odds ratio (95% CI)
Environmental factors			
Solid fuel for cooking			
(i) uses coal (%)	48·82	25·93	2·70 (1·56–4·76)
(ii) uses wood (%)	59·84	23·70	4·76 (2·70–8·33)
(iii) uses cowdung (%)	64·57	25·18	5·56 (3·03–10·0)
(iv) any combination of the above three (%)	76·38	28·89	7·96 (4·39–14·50)
Keeps large animals, % (cow/buffalo/goat)	17·32	1·5	13·93 (3·68–88·91)
Keeps birds (including poultry), %	18·1	6·7	3·13 (1·28–7·69)
Mud floor house (%)	57·5	11·9	10·05 (5·14–19·88)
Father smokes	48·03	51·85	0·85 (0·51–1·44)
Asthma			
History of asthma in the child (%)	40·94	8·89	7·11 (3·39–15·19)
History of asthma in a sib (%)	14·17	5·93	2·62 (1·02–6·93)
History of asthma in parents (%)	22·05	9·63	2·65 (1·23–5·78)

the poor in India emit a massive amount of smoke when first lit and are usually fired outdoors. When the fire is well lit it emits much less smoke and is then brought indoors for cooking. Furthermore, in hot and humid countries homes are likely to be more open. Both these factors would mitigate some of the associated ill effects of smoke from a cooking stove. The association between solid fuel used for cooking and ALRI in children is most likely to be causal because the association is strong, is biologically plausible, has appropriate temporal sequence and is supported by other studies. A high proportion of the population uses such fuel in countries like India and China and, therefore, the population attributable risk would be very high. This finding, therefore, has an important health policy implication.

Outdoor air pollution has also been examined as a risk factor for respiratory morbidity and mortality in many epidemiological studies over many decades [8–12]. It is only recently during the last two decades that the adverse role of exposure to air pollutants in indoor environments for child health has been recognized [4, 5, 13–18]. Children are exposed to inhaled pollutants as they breathe air in both indoor and outdoor locations. The mainly indoor pollutants, arising out of the burning of solid fuels add substantially to the total burden of inhaled pollutants. The urban poor in a city like Calcutta are already exposed to the outdoor inhaled pollutants due to a high pollution level in the city. Infants and young children are likely to spend more time indoor and/or close to the mother who is involved in the cooking activity. Therefore, highly polluting fuel for cooking would directly affect the child. This finding emphasizes that one needs to examine pollution levels where the people spend most time as well as in places where the ambient pollution levels are high [19].

A history of asthma in a child was associated with more than sixfold higher risk of severe ALRI requiring hospitalization. This association remained strong (OR = 5·6) after adjusting for likely confounders. Acute respiratory infection in children prone to asthma appears to cause more severe symptoms requiring hospital admission and, therefore, is a good prognostic indicator for severe disease due to ARI. History of asthma should therefore, alert one to take

Table 4. *Risk factors for pneumonia in infants and children: adjusted analysis using logistic regression model (dependent variable = pneumonia)*

	Odds ratio (95% CI)	*P* value
Factor		
Used wood or coal or cowdung or any combination for cooking (Yes = 1; No = 0)	3·97 (2·00–7·88)	< 0·001
History of asthma in the child (Yes = 1; No = 0)	5·49 (2·37–12·74)	0·001
Poor composite economic status*	4·95 (2·38–10·28)	< 0·001
Keeps large animals (cow/buffalo/goat)	6·03 (1·13–32·27)	0·036
Keeps birds/hen	1·15 (0·32–4·13)	0·83
Malnourished (weight for age *Z* score $< -2 = 1$, else = 0)	1·50 (0·74–3·04)	0·26
⩾ 2 sibs (Yes = 1, No = 10)	1·40 (0·60–3·26)	0·43
Mother's education†		
1–5 years schooling	0·57 (0·23–1·42)	0·23
6–10 years schooling	0·61 (0·26–1·44)	0·26
> 10 years schooling	0·38 (0·08–1·69)	0·20

* Reference category: yes to 3 or 4 factors which are: owns TV (Yes = 1, No = 0); owns fan (Yes = 1, No = 0); house with cement floor and wall (Yes = 1, No = 0); income > median (Yes = 1, No = 0).
† Reference category = illiterate mothers.

prompt remedial measures when an attack of respiratory infection occurs in a child.

Keeping animals like goats, cows or buffalo remained an independent risk factor for pneumonia after adjusting for many confounding variables. Further studies particularly in peri-urban and rural communities where this practice is more common should be conducted to estimate the role of keeping animals for pneumonia in children.

In univariate analysis parental education had a strong association with pneumonia in infants and young children. However, in the logistic regression model, the effect of maternal education was no longer significant although the results were in the same direction and showed a similar gradient as in univariate analysis. Parental education is likely to operate through a set of proximate variables. We can speculate on the models for a causal pathway for parental education to beneficially influence occurrence of pneumonia in infants and children. Parental education may lead to better care seeking behaviour, better media access, smaller family size, more complete immunization and a better economic status. Poor economic status was also shown to increase the risk of pneumonia in infants and children. Better income could operate through better home, availability of a clean fuel for cooking, better media access through owning a TV etc. A poor house can also be directly linked to pneumonia because of dampness, lack of ventilation and a large fluctuation of day and night temperature, all of which can pre-dispose an infant to acute respiratory infection. Furthermore, families with a large number of children were also associated with pneumonia risk. This may be due to crowding or cross-infection or both.

ACKNOWLEDGEMENTS

We thank Dr Anup Mondal, Superintendent, doctors and health workers of B. C. Roy Memorial Hospital for Children, Calcutta for their assistance in conducting this study, Mr Zakir Hussain for data management and analysis and Mr Subodh Karmakar for typing and editing the manuscript.

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