Higher childhood pneumonia admission threshold remains in Lao PDR: an observational study

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ABSTRACT

Objectives WHO Integrated Management of Childhood Illness (IMCI) guidelines changed pneumonia hospitalisation criteria in 2014, which was implemented in Lao People’s Democratic Republic (Lao PDR) in 2015. We determined adherence to: current (2014) IMCI guidelines for children presenting to hospitals with pneumonia, current outpatient management guidelines and identified hospitalisation predictors.

Design Prospective observational study (January 2017 to December 2018).

Setting Outpatient and emergency departments of four hospitals in Vientiane, Lao PDR.

Patients 594 children aged 2–59 months diagnosed with pneumonia.

Main outcome measures Number of children diagnosed, hospitalised, managed, administered preventive measures and followed-up accordant with current guidelines.

Results Non-severe and severe pneumonia were correctly diagnosed in 97% and 43% of children, respectively. Non-severe pneumonia with lower chest wall indrawing (LCI) was diagnosed as severe in 15%. Hospitalisation rates were: 80% for severe pneumonia, 86% and 3% for non-severe pneumonia with and without LCI, respectively. Outpatient oral antibiotic prescribing was high (99%), but only 30% were prescribed both the recommended antibiotic and duration. Appropriate planned follow-up was 89%. Hospitalisation predictors included age 2–5 months (compared with 24–59 months; OR 3.95, 95% CI 1.90 to 8.24), public transport to hospital (compared with private vehicle; OR 2.60, 95% CI 1.09 to 6.24) and households without piped drinking water (OR 4.67, 95% CI 2.75 to 7.95).

Conclusions Hospitalisation practice for childhood pneumonia in Lao PDR remains more closely aligned with the 2005 WHO IMCI guidelines than the currently implemented 2014 iteration. Compliance with current outpatient antibiotic prescribing guidelines was low.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Recent WHO severe pneumonia definition changes will result in apparent decreases in hospitalisation rates for severe pneumonia in the absence of any intervention.
⇒ The impact of these changes in high childhood mortality settings such as Lao People’s Democratic Republic (Lao PDR) has not been studied widely.
⇒ There are few studies evaluating hospitalisation predictors for childhood pneumonia in low-income and middle-income countries (LMICs).

WHAT THIS STUDY ADDS

⇒ Correct classification of pneumonia with lower chest wall indrawing but without general danger signs (previously severe pneumonia) as non-severe pneumonia is high in Lao PDR.
⇒ Admission practice for childhood pneumonia remains more closely aligned with previous, rather than current, Integrated Management of Childhood Illness (IMCI) guidelines.
⇒ Adherence to outpatient antibiotic prescribing guidelines for childhood pneumonia is low but adherence to illness prevention measures is high.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Understanding the use of and adherence to IMCI definitions and management recommendations is crucial to measuring the impact of childhood pneumonia interventions.
⇒ Factors affecting pneumonia admission practice outside of guideline change in high-childhood mortality LMICs requires further research.
⇒ Factors affecting antibiotic prescribing practice in high-childhood mortality LMICs requires further research.

BACKGROUND

Pneumonia is the leading cause of postneonatal mortality in children under 5 years, the majority occurring in low-income and middle-income countries (LMICs) 1,2. Diagnosis remains clinical, with microbiological and radiological tests providing minimal improvement in diagnostic sensitivity and specificity.3 To standardise diagnosis, the WHO developed clinical definitions of pneumonia and severe pneumonia, outlined in the 2005 Integrated Management of Childhood Illness (IMCI) guidelines.3,4 Aimed at integrating prevention, diagnosis and treatment of common childhood illnesses, these guidelines defined pneumonia as cough with tachypnoea (>50 breaths per minute and >40 breaths per minute for 2–11 months and 12–59 months). Children with pneumonia and lower chest wall indrawing (LCI), stridor or any general danger signs (eg, inability to drink) were classified as having severe pneumonia or very severe disease, requiring hospitalisation and parenteral antibiotics. Many LMICs have since adopted these guidelines.

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Given the challenges of hospitalisation in LMICs—unreliable medicine supply, costs to families, nosocomial infection, healthcare access—and several non-inferiority studies conducted in LMICs compared outpatient oral antibiotics and inpatient parenteral antibiotics for pneumonia with LCI, and found no difference in treatment failure. A systematic review subsequently concluded the evidence was low quality, with further research required, however the WHO proceeded to modify pneumonia definitions and management recommendations in 2014. LCI ceased to be a criterion for hospitalisation and parenteral antibiotics.

These modifications are likely to result in pneumonia hospitalisation rate changes in LMICs with widespread IMCI guideline use. A recent observational study of six LMICs, including Lao People’s Democratic Republic (Lao PDR), reported an apparent decrease for infants aged 2–23 months in: (1) Severe pneumonia hospitalisations by up to 50%, and (2) Annual incidence of severe pneumonia by up to 3423 per 100000 infants when comparing 2005 and 2014 IMCI definitions.

The impact of case definition changes on childhood pneumonia hospitalisation practice has not been widely studied in high-mortality settings. This study in Lao PDR aims to determine the adherence to current (2014) IMCI diagnosis and hospitalisation guidelines with reference to LCI, and current outpatient management guidelines; and to describe predictors of hospitalisation.

METHODS

Study site

Largely rural, Lao PDR ranks among the poorest South-East Asian countries. The estimated population of 7.27 million has 797 000 children under 5 years and an under-5 years mortality rate of 46 deaths per 1000 live births—the highest in the region. The capital Vientiane comprises 13% of the population, 78 000 being under 3 years. Public health services operate under a user-pays system, with only 12.5% of the total population medically insured. Vientiane has five hospitals with paediatric wards, where pulse oximetry is routinely available.

The IMCI guidelines were first implemented in Lao PDR in 1999. The Lao language version of the WHO Pocketbook of Hospital Care for children, incorporating the 2005 IMCI pneumonia definition, was introduced in 2010, updated with the new (2014) definition in 2013, and distributed across paediatric services in 2016.

Study design

This multicentre prospective observational study was conducted in the outpatient and emergency departments of four Vientiane hospitals with paediatric wards—Mahosot Hospital, National Child Hospital, Sêtathirat Hospital and Vientiane Provincial Hospital—between January 2017 and December 2018.

Study procedures

All children aged 2–59 months presenting to hospital and diagnosed with pneumonia of any severity by the treating clinician were eligible.

Following written informed consent by parent or guardian, data collection forms (DCFs) were completed by the treating clinician at first presentation. A complete list of variables collected is available in online supplemental appendix 1. In order to determine adherence to diagnosis, management and prevention guidelines, variables related to clinical features, diagnosed pneumonia severity, management and preventive measures were recorded. To determine hospitalisation predictors, variables related to patient demographics, household environment, parental education, exclusive breast feeding and comorbidities were recorded.

For those managed as outpatients, a second DCF was completed by the treating clinician at follow-up, and clinical features and management variables were recorded. Two weeks following initial presentation, participants were contacted by the study team via telephone to determine remaining symptoms and outcome. All available phone numbers for participants’ households were recorded at initial presentation. Where initial telephone contact was unsuccessful, three further attempts to make contact over the subsequent month using all provided phone numbers were made, after which they were deemed lost to follow-up.

Definitions

Current (2014) and previous (2005) IMCI case definitions for pneumonia and severe pneumonia were used.

Current case definitions: non-severe pneumonia was defined as cough and/or difficulty breathing, and tachypnoea (age-specific) and/or LCI; severe pneumonia was defined as having criteria for pneumonia with at least one general danger sign including inability to drink, persistent vomiting, convulsions, lethargy, unconsciousness, stridor in calm child, severe malnutrition, central cyanosis or oxygen saturations less than 90% in room air.

Previous case definitions: non-severe pneumonia was defined as cough and/or difficulty breathing, and tachypnoea (age-specific); severe pneumonia was defined as having criteria for pneumonia and LCI; very severe disease was defined as having criteria for pneumonia with at least one general danger sign (as above, except oxygen saturations less than 90% in room air).

The following criteria were used to define adherence to current IMCI management guidelines: prescription of oral amoxicillin for 3 days if non-severe pneumonia without LCI and 5 days with LCI, and planned outpatient follow-up in 3 days; for severe pneumonia, hospitalisation and commencement of intravenous antibiotics.

The following criteria were used to define whether children had received appropriate preventive measures according to current IMCI illness prevention guidelines: vitamin A in the preceding 6 months for those older than 6 months; deworming treatment in the preceding 6 months for those older than 12 months; age-appropriate vaccinations according to the Lao PDR national schedule (BCG and hepatitis B vaccines at birth; diphtheria, tetanus, pertussis, hepatitis B, Haemophilus influenzae type B, pneumococcal and polio vaccines at 2 months, 4 months and 6 months; measles vaccine at 12 months). Correlation with hand-held immunisation records was performed where available.

Case fatality was defined as death occurring within 14 days of discharge home.

Data management and statistical analysis

Data were double entered onto EpiData (V.3.1); statistical analysis was performed using Stata (V.14, Stata Corporation, College Station, Texas, USA). Categorical variables were summarised using frequency distributions; continuous variables using means and SD, or medians and IQRs as appropriate. Where there were missing values, analyses were performed using available data, and missing data rates are reported.

A complete list of variables evaluated as hospitalisation predictors is available in online supplemental appendix 2. To identify
predictors of hospitalisation, univariable logistic regression was performed, and unadjusted ORs and 95% CIs reported. Adjusted ORs and 95% CIs were calculated using multivariable logistic regression which included variables selected \textit{a priori} based on the literature (two or more people less than 5 years old in household, household biofuel exposure, household cigarette smoke exposure), \textsuperscript{16–18} and any variables with p<0.2 by univariable analysis.

The final regression model used data from those with complete data on all model variables and collinearity was checked using the variance inflation factor.

**Sample size**

To address the primary objective of determining adherence to current diagnosis and hospitalisation guidelines, a precision-based sample size calculation was performed. The calculation assumed that pneumonia admission practice would still concur with previous guidelines, with the majority of children with pneumonia and LCI hospitalised. Assuming hospitalisation of 90% of children with pneumonia and LCI, we calculated a sample size of 140 cases with pneumonia and LCI and/or general danger signs was required to estimate the percentage adherence to current hospitalisation guidelines with 95% CIs of width±5%.

We estimated that 600 children diagnosed with pneumonia of any severity would be required to meet the sample size requirement of 140 children with pneumonia and LCI and/or general danger signs. Data from children with pneumonia of any severity were included in the hospitalisation predictors analysis.

**RESULTS**

There were 594 eligible children enrolled between January 2017 and December 2018. Table 1 reports participant characteristics. The median age of participants was 19 months (IQR 10–30 months); the the most common age category was 24–59 months (78.1%), and almost 90% of participants had previous exposure to exclusive breastfeeding by carer report.

Table 2 reports classification, management and outcomes of participants. According to current pneumonia case definitions, 13.5% of participants had severe pneumonia. Those with pneumonia and LCI but without general danger signs (previously classified ‘severe pneumonia’) comprised 14.6% of participants. Of these, the majority (85.1%) were diagnosed correctly as non-severe pneumonia, but most (86.2%) were hospitalised. Case fatality in those with severe pneumonia was 2.5% (two hospitalised participants). A fifth of participants were unable to be contacted for follow-up.

Adherence to outpatient pneumonia antibiotic guidelines was low (30.8%), although over 50% were prescribed amoxicillin of any duration and almost all were prescribed an antibiotic (table 3). Antibiotic prescribing outside guideline recommendations mainly comprised broad-spectrum antibiotics (table 3). Median duration of any oral antibiotic prescription was 3 days (IQR 3–3) and oral amoxicillin prescription outside of recommended guidelines was 2 days (IQR 2–2). Adherence to illness prevention guidelines was high for deworming (82%), vitamin A (70%) and age-appropriate immunisations (93%).

Table 4 reports univariable and multivariable logistic regression results for hospitalisation predictors. Complete data were available for 537 participants (90.4%) included in the final multivariable logistic regression model. Being aged 2–5 months was strongly positively associated with hospitalisation when compared with 24–59 months (OR 3.95, 95%CI 1.90 to 8.24), participants who travelled to hospital using public transport compared with private vehicle, and lived in households without piped drinking water also had higher odds of hospitalisation (OR 2.60, 95%CI 1.09 to 6.24; OR 4.67, 95%CI 2.75 to 7.95 respectively).

**DISCUSSION**

To our knowledge, this is the first study to evaluate adherence to current IMCI guidelines for diagnosis, hospitalisation, management and prevention of childhood pneumonia, as well as hospitalisation predictors for children with pneumonia in South-East Asia. We have demonstrated that with the most recent changes to WHO pneumonia definitions, correct pneumonia severity classification is reasonably high, but adherence to current hospitalisation recommendations is low, suggesting that admission practice has not yet changed from previous guidelines. Moreover, although antibiotics were prescribed, adherence to outpatient oral antibiotic prescribing guidelines was low. Adherence to recommended illness prevention measures was high.

Changes to WHO pneumonia definitions in 2014 aimed to relieve the burden of hospitalisation to families, communities and governments for children with non-severe pneumonia with...
mortality in high-mortality settings where bacterial pneumonia rates are high.21 22 In high-childhood mortality LMICs, little is known about the impact these changes will have on mortality, and understanding the use of IMCI definitions and management recommendations becomes crucial to measuring impact. Prescription of an antibiotic occurred in most outpatient-managed pneumonia cases, however the correct antibiotic and duration was low in our study. This finding is consistent with reports of variable, inconsistent antibiotic prescribing in LMICs.23 Recent clinical trials have demonstrated lower treatment failure rate with amoxicillin compared with placebo for non-severe pneumonia with tachypnoea.24 25 as well as non-inferiority of 5 days versus 3 days of amoxicillin for non-severe pneumonia with LC1.26 This further highlights the importance of research into factors affecting prescribing practice, as well as ongoing training in IMCI guideline implementation to improve clinical care and outcomes.13 27

To our knowledge, there are no other studies to date examining potential childhood pneumonia hospitalisation predictors in South-East Asia. Consistent with our findings, several studies conducted in LMICs in other regions also demonstrated young age to be strongly predictive of hospitalisation.28–32 Two studies examining demographic and environmental factors found low socioeconomic status, household smoke exposure and low parental education levels to be significant.31 32 We found these factors to be significant in univariable analysis, but not in our multivariable model. Travel to hospital via public transport, and use of non-piped household water were significant predictive factors in our study, but not in other comparable studies.

Household income was not found to be predictive in our final multivariable model. Reluctance to raise the admission threshold in LMICs.23 Recent clinical trials have demonstrated lower treatment failure risk with amoxicillin compared with placebo for non-severe pneumonia with tachypnoea.24 25 as well as non-inferiority of 5 days versus 3 days of amoxicillin for non-severe pneumonia with LC1.26 This further highlights the importance of research into factors affecting prescribing practice, as well as ongoing training in IMCI guideline implementation to improve clinical care and outcomes.13 27

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### Table 2 Classification, management and outcomes of children aged 2–59 months presenting to central hospitals in Vientiane, Lao PDR with pneumonia (n=594)

<table>
<thead>
<tr>
<th>Pneumonia category, n (%)</th>
<th>Classification, n (%)</th>
<th>Management, n (%)</th>
<th>Outcome at follow-up phone call††, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia without LC1** or general danger signs†, n (%)</td>
<td>Classified as non-severe pneumonia</td>
<td>Admitted to hospital</td>
<td>Better</td>
</tr>
<tr>
<td>427 (71.9)</td>
<td>427 (100.0)**</td>
<td>13 (3.0)††</td>
<td>326 (76.3%)</td>
</tr>
<tr>
<td>87 (14.6)</td>
<td>74 (85.1)††</td>
<td>75 (86.2)§§</td>
<td>64 (73.6%)</td>
</tr>
<tr>
<td>80 (13.5)</td>
<td>46 (57.8)††</td>
<td>12 (13.8)‡‡</td>
<td>21 (26.2%)</td>
</tr>
</tbody>
</table>

Pneumonia (2005) defined as: cough or dyspnoea, and tachypnoea (>50 breaths per minute (bpm) if 2–11 months old; or >40 bpm if 12–59 months old). Pneumonia (2014) defined as: cough or dyspnoea, and one of either tachypnoea or chest indrawing. Severe pneumonia (2005 and 2014) defined as: criteria for pneumonia, plus either central cyanosis, or oxygen saturation <90% in room air, severe respiratory distress, inability to drink, lethargy, unconsciousness or convulsions.

*Lower chest indrawing.
†Non-severe pneumonia as per 2005 and 2014 WHO pneumonia definitions.
‡Non-severe pneumonia as per 2014 WHO pneumonia definition (as above). Severe pneumonia as per 2005 definition.
§Severe pneumonia as per 2005 and 2014 WHO pneumonia definitions.
¶WHO recommendation for children >6 months of age.
§§Denominator is those 12 months and over only (n=427) with available data.
**As per parent report or recorded in parent-held record.
††WHO recommendation for children >12 months of age.
‡‡Denominator is those 12 months and over only (n=427) with available data.
§§§WHO recommendation for children >6 months of age.
¶¶As per treating doctor.
†††Consistent with 2005 and 2014 WHO pneumonia definitions.
‡‡‡Consistent with 2014 WHO pneumonia definition.
§§§Consistent with 2005 WHO pneumonia definition.
¶¶¶Follow-up phone call planned for 2 weeks following initial presentation. Median time for follow-up phone call 21 days (IQR 16–29).
****One or more of the following symptoms: dry cough, productive cough, difficulty breathing, lethargy, inability to drink, vomiting or convulsions.
Lao PDR, Lao People’s Democratic Republic; LC1, lower chest wall indrawing.

Lao PDR. Our study suggests, however, that while pneumonia severity classifications may have changed, admission practice remains unchanged. In neighbouring Vietnam, a recent study found high incidence of hospitalisation for non-severe respiratory illness, perhaps related to perceived community expectations and historical use of aggressive therapy (eg, intravenous antibiotics) in such cases.19 In Lao PDR, the under-5 years mortality rate is the highest in South-East Asia, but has reduced by 70% since 1990.11 Reluctance to raise the clinical admission threshold in high-childhood mortality settings may reflect perceived clinician need to lower the treatment failure risk through hospitalisation, in order to continue reducing mortality. It is conceivable that other high-childhood mortality LMICs face similar pressure, and factors affecting admission practice outside of guideline changes require further research.

Understanding adherence to guidelines is also important for pneumonia impact evaluations. Measuring the impact of vaccines, or other interventions, is challenging, not least because of the lack of highly sensitive and specific pneumonia definitions.20 Countries such as Lao PDR are often heavily reliant on administrative hospitalisation data to document disease burden. If pneumonia admission practice changes, the incidence of pneumonia hospitalisations appears to decline regardless of intervention.9 Moreover, LC1 has been independently associated with
transport and non-piped household water represented a more nuanced proxy for household income and socioeconomic status.

Study limitations included reliance on parental recall. Variables related to prior preventive measures may have been subject to recall bias—in particular, our reported rates of having ever exclusively breast fed and receiving age-appropriate immunisations are higher than reported elsewhere.33 Our cohort of participants also had access to hospitals, possibly underrepresenting those with lower healthcare access as evidenced by the few participants living in poverty, and the higher reported immunisation rates than the national average (56%).33 Further limitations of our study included loss to follow-up at 2 weeks postinitial presentation due to incorrect phone numbers. There were no fatalities in children with non-severe pneumonia and LCI, however the high loss to follow-up rate in this group raises the possibility of unrecorded fatalities, as well as underestimation of other outcomes, including those who were better and still unwell.

Despite these limitations, this study provides the first report of current adherence to IMCI guidelines for diagnosis, management and prevention of pneumonia, and hospitalisation predictors for childhood pneumonia. Specifically, it highlights that

### Table 4

Univariable and multivariable logistic regression (n=537) for predictors of hospitalisation for pneumonia in children aged 2–59 months in Vientiane, Lao PDR

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Admission n/N (%)</th>
<th>Unadjusted OR (95% CI)</th>
<th>P value</th>
<th>Adjusted OR (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24–59 mo</td>
<td>47/238 (19.7)</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12–23 mo</td>
<td>27/189 (14.3)</td>
<td>0.68 (0.41 to 1.14)</td>
<td>&lt;0.001</td>
<td>1.22 (0.63 to 2.35)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6–11 mo</td>
<td>28/97 (28.9)</td>
<td>1.73 (1.01 to 2.97)</td>
<td></td>
<td>0.59 (0.32 to 1.07)</td>
<td></td>
</tr>
<tr>
<td>2–5 mo</td>
<td>42/70 (60.0)</td>
<td>6.10 (3.43 to 10.83)</td>
<td></td>
<td>3.95 (1.90 to 8.24)</td>
<td></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>66/279</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>78/312</td>
<td>1.08 (0.74 to 1.57)</td>
<td></td>
<td>0.704</td>
<td></td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lao Loum</td>
<td>88/496</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>56/96</td>
<td>6.57 (4.11 to 10.49)</td>
<td>&lt;0.001</td>
<td>1.87 (0.96 to 3.67)</td>
<td>0.067</td>
</tr>
<tr>
<td><strong>Time taken to get to hospital</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1 h</td>
<td>85/461</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥1 h</td>
<td>59/129</td>
<td>1.37 (1.06 to 1.78)</td>
<td>0.017</td>
<td>1.06 (0.58 to 1.94)</td>
<td>0.847</td>
</tr>
<tr>
<td><strong>Mode of transport to hospital</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private vehicle</td>
<td>97/520</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public transport</td>
<td>44/63</td>
<td>9.97 (5.58 to 17.81)</td>
<td>&lt;0.001</td>
<td>2.60 (1.09 to 6.24)</td>
<td>0.032</td>
</tr>
<tr>
<td><strong>No of household members aged &lt;5 years</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;2</td>
<td>72/341</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥2</td>
<td>72/249</td>
<td>1.49 (1.02 to 2.18)</td>
<td>0.037</td>
<td>1.14 (0.71 to 1.84)</td>
<td>0.597</td>
</tr>
<tr>
<td><strong>Cigarette smokers in household</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>80/382</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>62/206</td>
<td>1.66 (1.13 to 2.45)</td>
<td>0.010</td>
<td>1.07 (0.63 to 1.80)</td>
<td>0.807</td>
</tr>
<tr>
<td><strong>Household fuel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-biofuel</td>
<td>13/114</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biofuel</td>
<td>131/478</td>
<td>1.59 (1.01 to 2.52)</td>
<td>0.047</td>
<td>1.55 (0.77 to 3.11)</td>
<td>0.223</td>
</tr>
<tr>
<td><strong>Household drinking water</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piped</td>
<td>34/336</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>110/255</td>
<td>6.80 (4.41 to 10.48)</td>
<td>&lt;0.001</td>
<td>4.67 (2.75 to 7.95)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Household income</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Above poverty line*</td>
<td>131/569</td>
<td>ref</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Below poverty line*</td>
<td>10/19</td>
<td>1.45 (1.03 to 2.04)</td>
<td>0.031</td>
<td>0.75 (0.18 to 3.18)</td>
<td>0.693</td>
</tr>
<tr>
<td><strong>Mother completed primary school</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>109/503</td>
<td>ref</td>
<td></td>
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</tr>
<tr>
<td>No</td>
<td>35/82</td>
<td>2.77 (1.71 to 4.50)</td>
<td>&lt;0.001</td>
<td>0.75 (0.36 to 1.59)</td>
<td>0.460</td>
</tr>
<tr>
<td><strong>Ever exclusively breast fed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>134/520</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>8/61</td>
<td>0.43 (0.20 to 0.93)</td>
<td>0.032</td>
<td>0.67 (0.28 to 1.57)</td>
<td>0.351</td>
</tr>
<tr>
<td><strong>Previous presentation for current illness</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>No</td>
<td>74/361</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>69/216</td>
<td>0.55 (0.38 to 0.81)</td>
<td>0.002</td>
<td>0.63 (0.39 to 1.02)</td>
<td>0.062</td>
</tr>
<tr>
<td><strong>All age-appropriate immunisations received</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>116/549</td>
<td>ref</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>28/43</td>
<td>6.91 (3.57 to 13.36)</td>
<td>&lt;0.001</td>
<td>1.47 (0.56 to 3.84)</td>
<td>0.433</td>
</tr>
</tbody>
</table>

*Poverty line less than 250000 Kip.34 Lao PDR, Lao People’s Democratic Republic.
admission practice for childhood pneumonia in Lao PDR, a high childhood mortality setting, has not changed despite recent WHO pneumonia definition changes. Our results should be taken into account when reviewing trends in the burden of childhood pneumonia and impacts of various interventions in high childhood mortality LMIC settings.

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Contributors RL and FR conceptualised and designed the study, AG and AWJ contributed to study design and protocol preparation. VS supervised data collection. MC and CT collected the data. CN contributed to statistical analysis. RL drafted the manuscript and undertook the analysis. All authors critically reviewed and approved the final manuscript. RL is the guarantor for the overall content.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Royal Children’s Hospital Human Research Ethics Committee, Melbourne, Australia (33777C) and University of Health Sciences Ethics Committee, Vientiane, Lao PDR (6680). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

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