Prevalence and factors associated with severe illness in West African children under 5 years of age detected with routine pulse oximetry in primary care

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ABSTRACT

Background The Integrated Management of Childhood Illness (IMCI) guidelines are symptom-based algorithms used to identify critically ill children under five in primary health centres (PHC) in resource-limited countries. Hypoxaemia, a life-threatening event, is clinically underdiagnosed. The Amélioration de l'Identification des détresses Respiratoires de l'Enfant/Improving Identification of Respiratory Distress in Children (AIRE) project implemented the routine use of pulse oximetry (PO) within IMCI consultations to improve the diagnosis and management of severe hypoxaemia (pulse blood oxygen saturation <90%) at PHC level in Burkina Faso, Guinea, Mali and Niger. In this context, we measured the prevalence of severe cases and their associated social and structural factors among outpatients.

Methods In 16 AIRE research PHC (4/country), all the children under five attending IMCI consultations, except those aged 2–59 months classified as simple case without cough or breathing difficulties, were eligible for the use of PO and enrolled in a cross-sectional study with parental consent. Severe IMCI+PO cases were IMCI severe cases or those with severe hypoxaemia.

Results From June 2021 to June 2022, 968 neonates (0–59 days) and 14 868 children (2–59 months) were included. Prevalence of severe IMCI+PO cases was heterogeneous between countries: 5.0% in Burkina Faso, 6.1% in Niger, 18.9% in Mali and 44.6% in Guinea. Among neonates, 21.9% (95% CI 19.3 to 24.6) were severe cases versus 12.0% (95% CI 11.4 to 12.5) in older children, of which 3.3% versus 0.8%, respectively (p<0.001), had severe hypoxaemia. The adjusted social and structural factors associated with disease severity common to all four countries were as follows: age <2 months or >2 years, IMCI consultation delay >2 days, home to PHC travel time >30 min.

Conclusion The prevalence of seriously ill children under five, including severe hypoxaemia, was high in PHC, particularly in neonates. The high between-country heterogeneity may be explained by differences in case definitions (Guinea) and structural factors (accessibility).

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ A few studies have reported the prevalence and correlates of severe illnesses with the Integrated Management of Childhood Illness (IMCI) guidelines using routine integration of pulse oximetry (PO) among all children under five at the primary health-care level in low- and middle-income countries (LMICs), but mainly outside of West Africa.

WHAT THIS STUDY ADDS

⇒ Our study reports a high prevalence of severe cases using IMCI guidelines integrating the routine use of PO among outpatient children under five attending IMCI consultations. There is variation between countries (Burkina Faso, Guinea, Mali, Niger).

⇒ We show that the overall prevalence of severe cases was almost twice as high in neonates (21.9%) as in children aged 2–59 months (12.0%). Similarly, the prevalence of severe hypoxaemia was higher in neonates (3.3%) than in older children (0.8%).

⇒ This study highlights the challenges of accessing primary healthcare for children under five with serious illnesses and the inadequacy of decisions regarding their specific care management.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our study provides policy makers with original and reliable estimates to inform investment in earlier access to primary healthcare and better referral decision for severe cases, with the aim of improving child health in West Africa.

⇒ These indicators will be useful for assessing the added value of integrating PO into IMCI consultations in LMICs, and for supporting the scaling up of routine PO use in both national and international IMCI guidelines.

Improving early access to primary care could be an actionable lever to improve the health of West African children.

INTRODUCTION

The Sustainable Development Goal 3 aims to reduce the mortality rate for children under 5 years to lower than 25 deaths per 1000 live births by 2030,[1–3] but this indicator still remains high. Globally, five million of children under five died in 2021. Sub-Saharan African and Asian countries contribute highly to this mortality estimated at 74 deaths per 1000 live births in 2021.[4] West African countries are particularly concerned. There, child mortality is associated with fragile health systems,[5] unskilled healthcare workers (HCW) and inaccurate recognition of severe disease at primary healthcare centres (PHC) due to the lack of diagnostic tools.[6–9] In 1996, the WHO therefore proposed the Integrated Management of Childhood Illness (IMCI) guidelines,[10] and its subsequent revisions[11 12] aimed to use symptom-based algorithms guiding HCW to better identify and manage severe cases at the PHC level in resource-limited countries. Each country adopted and adapted these guidelines to suit its own context. Some countries use a paper format, others an electronic one. This is coupled with other strategies aimed to improve malaria control, including the use of bed nets impregnated with long-acting insecticide,[13 14] malaria Rapid Diagnosis Tests (mRDT) in febrile children[15 16] and seasonal malaria chemoprevention,[17] and to improve the management of malnutrition,[18 19] intestinal parasitosis and other health conditions affecting children under five. However, even when these IMCI guidelines are used, diagnosing severe illnesses remains difficult and inaccurate, resulting in delayed and inappropriate care management.[20 21]

Severe hypoxaemia defined as low levels of oxygen in the blood (pulse blood oxygen saturation (SpO_2) <90%)[22] is a common manifestation of severe illness, but is underdiagnosed clinically when using IMCI alone.[23 24] The prevalence of severe hypoxaemia was estimated at 22% among sick inpatient neonates in Nigeria,[23] 1.3% among outpatients in Uganda[25] and up to 23% among children under five receiving outpatient care in sub-Saharan Africa.[26] Severe hypoxaemia is a strong predictor of mortality. In Malawi, children hospitalised with hypoxaemic pneumonia had the highest mortality rate (8.3%) compared with pneumonia with danger signs (5.4%), chest indrawing (2.1%) or only fast breathing (1.2%).[27] In Nigeria, children with severe hypoxaemia have six to seven times higher risk of death than those without.[23] Severe hypoxaemia should therefore be identified and managed more effectively in primary care. The routine use of pulse oximetry (PO) would enable its accurate detection, allowing for subsequent hospital referral for oxygen therapy.[28]

The Amélioration de l'Identification des détresses Respiratoires de l'Enfant/Improving Identification of Respiratory Distress in Children (AIRE) project was implemented by a consortium of three non-governmental organisations (NGO), Alliance for International Medical Action, Solthis and Terre des hommes (Tdh), and the French Institute of Health and Medical Research (Inserm). It aimed to improve the detection of severe hypoxaemia in children under 5 years of age and their care management at PHC level by introducing the routine use of PO within IMCI consultations in 202 PHCs in four West African countries: Burkina Faso, Guinea, Mali, Niger.[29] This special issue addresses several findings related to the outcomes for children diagnosed routinely using PO within IMCI consultations from the AIRE project.[30–33] The first concerns the epidemiology of severely ill children under 5 years of age identified, and the proportion with severe hypoxaemia. In the four AIRE study countries, this information was unavailable. The aim of this cross-sectional analysis was therefore to estimate the prevalence of severe cases and their associated structural and social factors among outpatients under 5 years of age at PHC level, in settings where IMCI guidelines incorporate the routine use of PO.

METHODS

Study sites

The AIRE operational research study took place in two health districts per country, in a total of eight district hospitals and 202 PHCs, including 16 research PHCs (four per country) according to the published protocol.[29] A baseline site assessment described the characteristics of the AIRE study context.[34]

Study design

A population-based cross-sectional study was conducted among IMCI children under 5 years of age in the 16 research PHC. Individual data have been collected to assess outcomes of PO introduction into IMCI consultations.

Study population and inclusion criteria

From 14 June 2021 to 20 June 2022, all the neonates (defined from 0 to 59 days) and children (from 2 to 59 months) attending IMCI consultations in the 16 research PHCs were screened by the site HCW using the national IMCI algorithms. Children were classified and managed based on their disease severity into three groups: green for simple cases (eligible to be sent home), yellow for moderate cases (observed and treated at PHCs, then at home) and red for severe cases requiring urgent hospital transfer. All the national IMCI guidelines were aligned except for 'chest indrawing' which was considered a severity sign in Guinea, whereas in Mali, Burkina Faso and Niger, this sign classified children as moderate cases. The AIRE research study proposed that after each IMCI consultation, PO should be used according to child' age and initial IMCI classification. PO use was implemented routinely into IMCI guidelines based either on electronic or paper support, for all the children under 5 years of age attending IMCI consultations, except those aged 2–59 months classified as simple non-respiratory cases, without cough or breathing difficulties. All the children initially classified as non-severe cases using IMCI (green and yellow cases) who had severe hypoxaemia (SpO_2 <90%)

using PO joined the severe case (red) group. Severe cases using the IMCI+PO approach were IMCI severe cases or those with severe hypoxaemia. Then, the dedicated AIRE study team proposed the child inclusion to all those eligible for PO use. Those whose parents gave the written consent were included.

Procedures

The usual procedures for the IMCI consultation and for carrying out mRDT had not been modified by the AIRE project. All the clinical parameters (axillary temperature, weight, height) were measured using a thermometer, child scale and height scale, in the triage room if available, or at the beginning of IMCI consultation. Then, PO (Acare Technology, Taiwan; AH-M1 S0002033) was used by onsite clinicians after IMCI classification to measure heart rate and oxygen saturation in blood (SpO_2) with appropriate probe according to age. These two parameters were recorded in the IMCI consultation registers.

Although clinicians had received refresher training in IMCI, they had not undergone training in research procedures, except for a general briefing on Good Clinical Practice. A separate team was dedicated to research data collection. Data were extracted by AIRE data collectors, who were generally nurses, from the paper-based register of consultation or the electronic database set up by the NGO Tdh in Burkina Faso and the Markala health district in Mali.

Data collection and definitions

Individual data collection had been carried out over the whole period of inclusion via electronic case report form with Research Electronic Data Capture (REDCap) software. These include sociodemographic data, clinical data about IMCI classification PO data and clinician' decision of care management at PHC.

In this study, neonates were defined until 59 days of age, according to the IMCI definition. Severe hypoxaemia was defined as an SpO_2 value below 90%, and moderate hypoxaemia as an SpO_2 level between 90% and 93%.[25 35] Normal heart rate (cardiac frequency) was defined between 100 and 160 beats per minute for children aged 0–1 year, between 90 and 150 for children aged 1–3 years and between 80 and 140 for those aged 3–5 years. Fever was defined as a body temperature of 38°C or higher, using digital thermometers.[36] In the AIRE study, axillary temperature was used and corrected by adding 0.5°C to the reading. Fast breathing was defined as a respiratory rate ≥60 breaths per minute for neonates aged 0–59 days, ≥50 breaths per minute for children aged from 2 to 11 months inclusive and ≥40 breaths per minute for those aged from 12 to 59 months inclusive.[12] A respiratory case was defined if the clinician identified at least one respiratory symptom such as cough, cold, wheezing, stridor at rest, chest tightness, or rapid or difficult breathing.

Statistical analysis

First, we described the sociodemographic and clinical characteristics of children under the age of five—eligible for PO during IMCI consultations, both overall and by
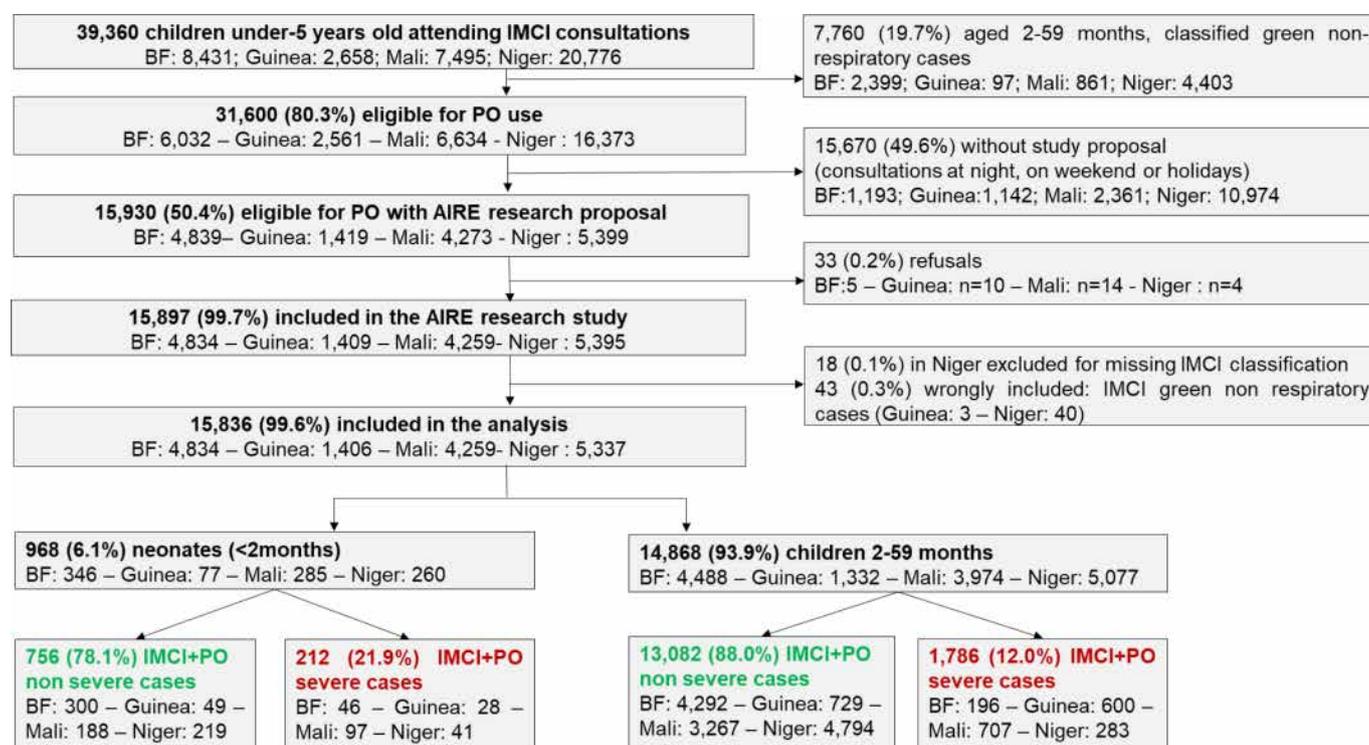
Figure 1 Flow chart of inclusion process in the AIRE research study according to child age, June 2021–June 2022. AIRE, Amélioration de l'Identification des détresses Respiratoires de l'Enfant/Improving Identification of Respiratory Distress in Children; BF, Burkina Faso; IMCI, Integrated Management of Childhood Illness; PO, pulse oximetry.

country: distributions by age, sex, number of people living in the household, education level of the household responsible person, income-generating activity of the accompanying person, distance from the home to PHC, rural/urban PHC, PO uptake, SpO$_2$ level measurement (severe and moderate hypoxaemia) after PO use, severe cases using IMCI+PO classification, combining the standard IMCI classification and severe hypoxaemia diagnosed using PO, IMCI support (paper/electronic), severe cases (respiratory or non-respiratory), and proportions among severe cases with hospital transfer decided by HCW. Quantitative data were described using means and SD or medians and IQRs and were compared using Kruskal-Wallis Test. Categorical data were described as proportions with their 95% CIs and were compared using Pearson χ^2 or Fisher exact tests. All analyses were considered statistically significant with a p value less than 0.05.

We then compared the main characteristics according to disease severity for the whole sample and analysed the factors associated with severe disease, using a generalised linear mixed-effects regression model with a random country effect. An explanatory model was computed using univariate analysis, and a full model adjusted included the relevant variables or those associated with a p value <0.20 in the univariate analysis. We report the adjusted OR (aOR) with its 95% CI. The variables explored were the following: age and sex (forced), mother's vital status and literacy level, existing income-generating activity, travel time from the home to PHC (>30 min), consultation delay (>2 days) since the onset of symptoms, and the type of IMCI support (paper or electronic). A two-tailed p value of <0.05 was regarded as statistically significant. R software V.4.0.5 was used.

Patient and public involvement

This study was conducted using individual data collected with ethical committees and ministries' authorisations. Patients were not involved in the design, conduct, writing or dissemination plans of our research.

RESULTS
Flow chart
During the inclusion period, 39 360 children under five attended IMCI consultations in the 16 research PHCs (flow chart, figure 1). Among them, 7760 (19.7%) simple non-respiratory IMCI cases were not eligible for the use of PO. Among the 31 600 (80.3%) children eligible for PO, 15 670 (49.6%) sought services at night or over the weekends when study data collectors were not at the PHC and were not offered enrolment into the study. Among the 15 930 (50.4%) remaining who were offered the study, 33 (0.2%) families refused, mainly because the child's accompanying person needed the father' authorisation, and 15 897 (99.7%) were included in the study with parental consent, of whom 61 (0.4%) were excluded from the analysis for missing IMCI classification or wrong inclusion. Overall, 15 836 (99.6% of those included)

were considered in the analysis, including 968 (6.1%) neonates (0–59 days) and 14 868 (93.9%) children (2–59 months) (figure 1).

Sociodemographic characteristics of study participants
Table 1 shows the sociodemographic characteristics of the 15 836 children included, globally and by country. Overall, 6.1% of the children were neonates, ranging from 4.9% in Niger to 7.2% in Burkina Faso. Female sex was under-represented, accounting for 47.2% of the whole sample. The median number of people living with the child ranged from five in Burkina Faso, Guinea and Niger to nine in Mali. Overall, the household responsible person had never attended school in 65.1% of cases, ranging from 49.1% in Guinea to 82.4% in Burkina Faso. The child's mother was still alive in 99.6% of cases. The person accompanying the child on the day of the consultation was the mother or father in 98.0% of cases. This person was married or in a civil union in 98.3% of cases. Overall, 81.0% of children lived within 30 min of the PHC they visited. In 61.2% of cases, families travelled to the PHC on foot, by cart or by bike free of charge (ranging from 23.2% in Mali to 83.0% in Burkina Faso), while in 38.6% of cases, families travelled by vehicle, motorcycle or bus (private or public transport) with percentages ranging from 16.0% in Niger to 77.1% in Mali. Children were first seen at the IMCI consultations after a median delay of 2 days from the onset of symptoms, except in Guinea, where it took 3 days.

Clinical characteristics, prevalence of severe illness after IMCI+PO classification and HCW's decision
The clinical characteristics of the 15 836 children included and outcomes of the IMCI consultations integrating the use of PO differed significantly according to age and country (online supplemental table 1).

Among the 968 neonates included, 6.1% had low birth weight, varying significantly from 1.3% in Guinea to 10.7% in Burkina Faso. Breastfeeding in the first months of life was the rule with 98.0% neonates breastfed at the time of visit. Prior to the IMCI consultation, 5.8% had received medication, varying from 2.6% in Burkina Faso to 9.2% in Niger. The main reasons for consultation reported by the accompanying person were cough or respiratory difficulties for 47.1% of all the neonates, reported fever (47.0%), vomiting (6.2%) and diarrhoea (3.9%). After the IMCI consultation, documented fever (T $\geq$38°C) was measured in 9.2% of the neonates ranging from 2.8% in Mali to 26.0% in Guinea, while hypothermia (T <35°C) affected only 0.4% of them. Bradycardia was noted in 4.1% while fast heart rate (tachycardia) was measured in 17.0%; 35.8% were classified as respiratory cases. Hypoxaemia (SpO$_2$ $\leq$93%) was prevalent in 18.3% of all neonates: 3.3% (95% CI 2.3 to 4.6) severe hypoxaemia and 14.8% (95% CI 12.6 to 17.2) moderate hypoxaemia. Severe hypoxaemia varied significantly from 1.7% in Burkina Faso to 6.3% in Mali. After IMCI classification and use of PO, the prevalence of severe cases

Table 1 Global and by-country sociodemographic characteristics of IMCI outpatient children enrolled at PHC level in the AIRE research project, June 2021–June 2022 (N=15 836).

Variables	Statistics	Burkina Faso N=4834	Guinea N=1406	Mali N=4259	Niger N=5337	Total N=15 836	P value
Age groups (in months)	<2, n (%)	346 (7.2)	77 (5.5)	285 (6.7)	260 (4.9)	968 (6.1)	<0.001
	2–23	2467 (51.0)	757 (53.8)	2052 (48.2)	3284 (61.5)	8560 (54.1)	
	24–59, n (%)	2021 (41.8)	572 (40.7)	1922 (45.1)	1793 (33.6)	6308 (39.8)	
Sex	Female, n (%)	2301 (47.6)	693 (49.3)	1967 (46.2)	2520 (47.2)	7481 (47.2)	0.21
Number of people living in household	Median (Q1; Q3)	5 (4; 10)	5 (4; 6)	9 (4; 16)	5 (4; 7)	5 (4; 9)	<0.001
	Missing, n (%)	0 (0.0)	0 (0.0)	4 (0.1)	7 (0.1)	11 (0.1)	
Deceased mother	Yes, n (%)	18 (0.4)	3 (0.2)	12 (0.3)	29 (0.5)	62 (0.3)	0.129
	No, n (%)	4816 (99.6)	1403 (99.8)	4244 (99.6)	5304 (99.4)	15 767 (99.6)	
	Missing, n (%)	0 (0.0)	0 (0.0)	3 (0.1)	4 (0.1)	7 (0.1)	
Education level of household responsible person	Never attended school, n (%)	3982 (82.4)	691 (49.1)	2848 (66.9)	2787 (52.2)	10 308 (65.1)	<0.001
	Primary school, n (%)	389 (8.0)	260 (18.5)	996 (23.4)	1110 (20.8)	2755 (17.4)	
	Secondary school, n (%)	424 (8.8)	340 (24.2)	398 (9.3)	1280 (24.0)	2442 (15.4)	
	University, n (%)	39 (0.8)	115 (8.2)	13 (0.3)	152 (2.8)	319 (2.0)	
	Missing, n (%)	0 (0.0)	0 (0.0)	4 (0.1)	8 (0.2)	12 (0.1)	
Child's accompanying person	Mother, n (%)	4731 (97.8)	1358 (96.6)	4151 (97.5)	5173 (97.0)	15 413 (97.3)	<0.001
	Father, n (%)	13 (0.3)	12 (0.8)	27 (0.6)	56 (1.0)	108 (0.7)	
	Others, n (%)	90 (1.9)	36 (2.6)	77 (1.8)	100 (1.9)	303 (1.9)	
	Missing, n (%)	0 (0.0)	0 (0.0)	4 (0.1)	8 (0.1)	12 (0.1)	
Income-generating activity of accompanying person	Yes, n (%)	963 (19.9)	720 (51.2)	1020 (23.9)	1106 (20.7)	3809 (24.0)	<0.001
	No, n (%)	3871 (80.1)	686 (48.8)	3235 (76.0)	4224 (79.1)	12 016 (75.9)	
	Missing, n (%)	0 (0.0)	0 (0.0)	4 (0.1)	7 (0.2)	11 (0.1)	
Accompanying person's family situation	Currently married/coupled, n (%)	4714 (97.5)	1372 (97.6)	4206 (98.8)	5271 (98.8)	15 563 (98.3)	<0.001
	Divorced, widowed, single, refusal to answer, n (%)	120 (2.5)	34 (2.4)	49 (1.2)	60 (1.1)	263 (1.6)	
	Missing, n (%)	0 (0.0)	0 (0.0)	4 (0.1)	6 (0.1)	10 (0.1)	
Travel time from home to PHC	Less than or equal to 30 min, n (%)	4330 (89.6)	1061 (75.5)	3050 (71.6)	4390 (82.2)	12 831 (81.0)	<0.001
	More than 30 min, n (%)	504 (10.4)	345 (24.5)	1205 (28.3)	943 (17.7)	2997 (18.9)	
	Missing, n (%)	0 (0.0)	0 (0.0)	4 (0.1)	4 (0.1)	8 (0.1)	

Table 1 Continued

Variables	Statistics	Burkina Faso N=4834	Guinea N=1406	Mali N=4259	Niger N=5337	Total N=15836	P value
How to get to the PHC	Foot/cart/bike, n (%)	4006 (83.0)	424 (30.2)	689 (16.1)	4269 (80.0)	9685 (61.2)	<0.001
	Car/motorcycle/bus: public or private transport, n (%)	842 (17.4)	886 (63.0)	3304 (77.5)	1097 (20.5)	6129 (38.7)	
Consultation time since onset of symptoms (in days)	Median (Q1; Q3)	2 (1; 2)	3 (2; 3)	2 (1; 3)	2 (1; 3)	2 (1; 3)	<0.001
	Missing, n (%)	95 (2.0)	6 (0.4)	35 (0.8)	28 (0.52)	164 (1.0)	
Care pathway before the consultation	Arrival from home, n (%)	4795 (99.2)	1394 (99.1)	4157 (97.6)	5109 (95.7)	15455 (97.6)	<0.001
	Arrived via another pathway, n (%)	39 (0.8)	12 (0.9)	102 (2.4)	228 (4.3)	381 (2.4)	

AIRE, Amélioration de l'Identification des détresses Respiratoires de l'Enfant/Improving Identification of Respiratory Distress in Children; IMCI, Integrated Management of Childhood Illness; PHC, primary health centres.

was estimated at 21.9% (212/968, 95% CI 19.3 to 24.6), with a substantial variation between countries, 13.3%, 15.8%, 34.0% and 36.4% in Burkina Faso, Niger, Mali and Guinea, respectively (online supplemental table 1). Overall, the clinician's decision to refer those neonates classified as severe cases was taken for 46.2% (95% CI 39.4 to 53.2), with high between-country heterogeneity: 32.0%, 32.1%, 60.9% and 73.2% in Mali, Guinea, Burkina Faso and Niger, respectively.

Of the 14868 children aged 2–59 months included, 12.5% had received medication prior to the IMCI consultation, varying from 9.9% in Niger to 17.3% in Mali. The main reasons for consultation, as reported by the accompanying person, were fever (84.3%), cough or respiratory difficulties (62.3%), followed by vomiting (16.9%) and diarrhoea (14.7%). Following the IMCI consultation, documented fever (T $\geq 38°C$) was noted in 45.4% of the children, varying from 44.1% in Mali and Niger to 53.5% in Guinea. Sixty-eight per cent (68.1%) of children were classified as respiratory cases. Hypoxaemia was prevalent in 10.4% of the children: 0.8% (95% CI 0.6 to 0.9) with severe hypoxaemia and 9.6% (95% CI 9.1 to 10) with moderate hypoxaemia. The prevalence of severe hypoxaemia varied significantly from 0.1% in Burkina Faso to 1.1% in Mali and Niger. Overall, 70.5% of children were classified as moderate cases using IMCI+PO: 49.8% in Guinea and around 72.0% elsewhere. The prevalence of severe cases identified with IMCI+PO was estimated at 12.0% (95% CI 11.4 to 12.5), with significant variations between countries: 4.4% in Burkina Faso, 5.6% in Niger, 17.8% in Mali and 45.1% in Guinea. After the consultation using IMCI+PO, HCWs made the decision to refer 29.4% of children classified as severe cases overall (95% CI 27.3 to 31.6), with significant between-country heterogeneity, 11.5% in Guinea, 16.1% in Mali and 71.4% in Burkina Faso and Niger (online supplemental table 1).

Factors associated with the identification of severe illness using IMCI+PO

Overall, of the 15836 children included, 1998 (12.6%) were classified as severe cases using the IMCI+PO classification. This included 212 (10.6%) neonates and 1786 (89.4%) older children (figure 1). The prevalence of severe cases varied significantly between countries, estimated at 5.0% (95% CI 4.4 to 5.7) in Burkina Faso, 6.1% (95% CI 5.4 to 6.7) in Niger, 18.9% (95% CI 17.7 to 20.1) in Mali and 44.7% (95% CI 42.0 to 47.3) in Guinea (figure 2).

Children aged <2 months and those aged 24–59 months were significantly more likely to be diagnosed as severe cases, 10.6% and 47.0%, respectively, than children aged 2–23 months (42.3%) (p<0.001) (table 2). Children whose household responsible person was illiterate or had no income-generating activity, living more than 30 min travel from the PHC, presenting with signs more than 2 days since the onset of symptoms, or who arrived through another care pathway of care were significantly more likely to be diagnosed as severe cases. Documented
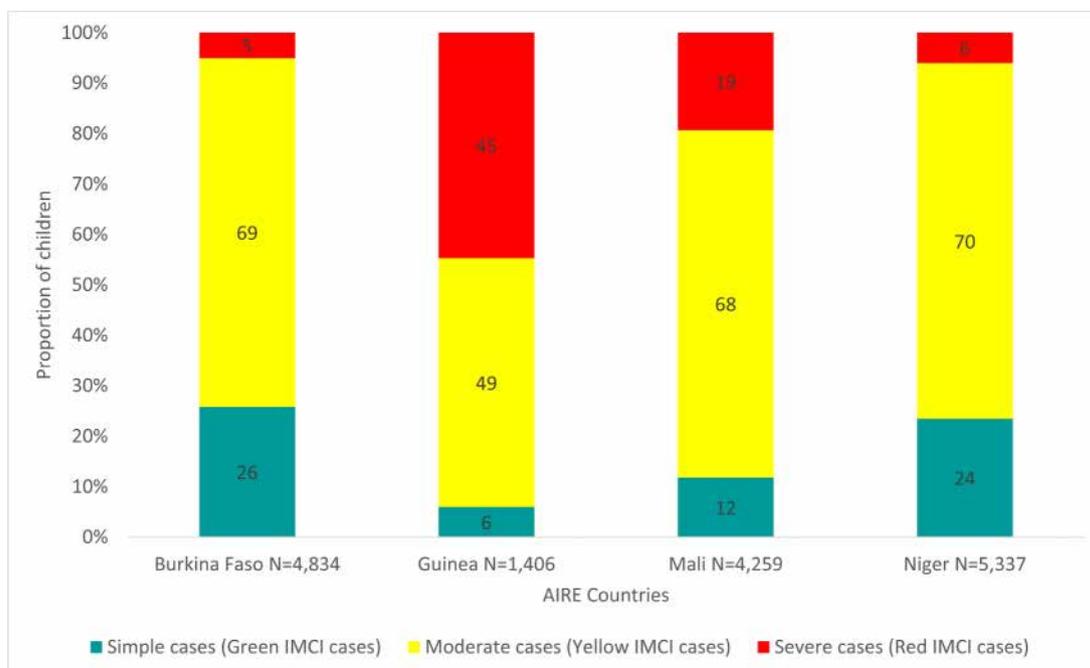
Figure 2 IMCI classification(in %) using PO of children under 5 years of age included at primary care level in the four AIRE countries' project, June 2021–June 2022. AIRE, Amélioration de l'Identification des détresses Respiratoires de l'Enfant/ Improving Identification of Respiratory Distress in Children; IMCI, Integrated Management of Childhood Illness; PO, pulse oximetry.

fever (p<0.001) and the absence of respiratory symptoms (p<0.001) were more common in severe cases than in non-severe cases.

Exploring social health factors associated with disease severity in a global generalised mixed linear model with a random country effect, adjusted on sex, income-generating activity of the household responsible person, the following factors were independently associated with an increased risk of illness severity (table 2): children aged under 2 months (aOR 2.58; 95% CI 2.11 to 3.16), and children aged 24–59 months (aOR 1.59; 95% CI 1.42 to 1.78) compared with those aged 2–23 months, children whose mother is deceased (aOR 2.49; 95% CI 1.23 to 5.05) and children whose accompanying person is illiterate (aOR 1.12; 95% CI 1.04 to 1.35), a delay of more than 2 days in seeking the PHC (aOR 1.95; 95% CI 1.74 to 2.18), travel time from the home to the PHC >30 min (aOR 1.47; 95% CI 1.29 to 1.68) and the use of a paper-based IMCI rather than an electronic IMCI (aOR 1.41; 95% CI 1.18 to 1.68).

We also carried out the same analyses for each country (online supplemental tables 2–5): the factors associated with the identification of severe cases varied from country to country.

DISCUSSION

Our study provides original epidemiological indicators of severe illnesses in four West African countries, using routine PO for outpatient children attending IMCI consultations at the frontline. These data were collected from children under 5 years of age (including neonates),

and using standardised tools that allow for comparisons between countries and age groups. Key findings are highlighted. First, the prevalence of children classified as severe cases using the IMCI+PO approach was high overall, but varied significantly between countries, ranging from 5.0% in Burkina Faso to 44.6% in Guinea. Second, the overall prevalence of severe cases was almost twice as high in neonates (21.9%) than in children aged 2–59 months (12.0%). Similarly, the overall prevalence of severe hypoxaemia was higher in neonates (3.3%) than in older children (0.8%). Third, common social health factors associated with disease severity at PHC were identified: young age (<2 months), older age (2–5 years), maternal death or illiteracy, as well as variables indicating delayed access to care: delay >2 days after the onset of symptoms and travel time of more than 30 min from home to the PHC. Fourth, in Mali, where a comparison of IMCI support was feasible, it was found that using a paper-based IMCI also independently increased the risk of being classified as severe by +41% compared with an electronic IMCI. Finally, clinicians at PHC made insufficient decisions of referral to hospital for children classified as severe cases using IMCI+PO, and this varied by countries and age group. Referral rates were higher for neonates (46.2%, ranging from 32.0% in Mali to 73.2% in Niger) than for older children (29.4%, ranging from 11.5% in Guinea to 71.5% in Burkina Faso).

Although a few studies have reported on the prevalence of severe cases using PO within IMCI among children under 5 years of age in low- and middle-income countries, none seem to have been conducted in West

Table 2 Sociodemographic, clinical distribution and factors associated with illness severity of IMCI children enrolled at PHC in the AIRE project, using a logistic regression model with a random country effect, AIRE project June 2021–June 2022 (1998 vs 13838)

Variables		Severe IMCI+PO cases		Total	Univariate analysis	Adjusted analysis
		Yes	No			
		N=1998	N=13838	N=15836	OR (95% CI)	aOR (95% CI)
Age (months)	<2, n (%)	212 (10.6)	756 (5.5)	968 (6.1)	2.88 (2.4 to 3.45)	2.58 (2.11 to 3.16)
	2–23, n (%)	846 (42.3)	7714 (55.7)	8560 (54.1)	–	–
	24–59, n (%)	940 (47.0)	5368 (38.8)	6308 (39.8)	1.56 (1.41 to 1.74)	1.59 (1.42 to 1.78)
Sex	Male, n (%)	1038 (52.0)	7317 (52.9)	8355 (52.7)	–	–
	Female, n (%)	960 (48.0)	6521 (47.1)	7481 (47.2)	1.03 (0.93 to 1.14)	1.01 (0.91 to 1.12)
Deceased mother	No, n (%)	1986 (99.4)	13781 (99.6)	15767 (99.6)	–	–
	Yes, n (%)	12 (0.60)	50 (0.4)	62 (0.4)	2.35 (1.23 to 4.51)	2.49 (1.23 to 5.05)
Ability to read and write of the household responsible person	Yes, n (%)	479 (24.0)	3947 (28.5)	4426 (27.9)	–	–
	No, n (%)	1519 (76.0)	9884 (71.4)	11403 (72.1)	1.33 (1.18 to 1.51)	1.19 (1.04 to 1.35)
Income-generating activity of accompanying person	Yes, n (%)	562 (28.1)	3247 (23.5)	3809 (24.1)	–	–
	No, n (%)	1436 (71.9)	10580 (76.5)	12016 (75.9)	1.27 (1.13 to 1.43)	1.12 (0.99 to 1.28)
Travel time from home to PHC	Less than or equal to 30 min, n (%)	1448 (72.5)	11383 (82.3)	12831 (81.1)	–	–
	More than 30 min, n (%)	550 (27.5)	2447 (17.7)	2997 (18.9)	1.37 (1.22 to 1.54)	1.47 (1.29 to 1.68)
Consultation time since onset of symptoms	≤2 days, n (%)	903 (49.3)	9974 (75.6)	10877 (68.7)	–	–
	>2 days, n (%)	930 (50.7)	3219 (24.4)	4149 (26.2)	2.02 (1.81 to 2.25)	1.95 (1.74 to 2.18)
Care pathway before IMCI consultation	Arrival from home, n (%)	1889 (94.5)	13566 (98.0)	15455 (97.5)	–	*
	Arrival via another pathway, n (%)	109 (5.5)	272 (2.0)	381 (2.5)	4.13 (3.23 to 5.28)	–
IMCI support	Electronic-based	649 (32.4)	6647 (48.0)	7296 (46.1)	–	–
	Paper-based	1349 (67.5)	7191 (51.9)	8540 (53.9)	1.44 (1.23 to 1.68)	1.41 (1.18 to 1.68)
Child's accompanying person	Mother, n (%)	1937 (96.9)	13476 (97.4)	15413 (97.4)	–	*
	Father, n (%)	12 (0.6)	96 (0.7)	108 (0.7)	0.78 (0.42 to 1.47)	–
	Others, n (%)	90 (4.5)	36 (2.6)	303 (1.9)	1.27 (0.91 to 1.78)	–
Documented fever	No, n (%)	820 (41.0)	7689 (55.6)	8509 (53.7)	–	–
	Yes (T ≥38°C), n (%)	1082 (54.2)	5760 (41.6)	6842 (43.2)	1.4 (1.25 to 1.56)	–
Respiratory cases	No, n (%)	897 (45.5)	4162 (30.7)	5059 (31.9)	–	*
	Yes, n (%)	1075 (54.5)	9402 (69.3)	10477 (66.2)	0.57 (0.51 to 0.63)	–

C-stat=0.79.

*Not included in the adjusted model for statistical or clinical reasons.

AIRE, Amélioration de l'Identification des détresses Respiratoires de l'Enfant/Improving Identification of Respiratory Distress in Children; AOR, adjusted OR; IMCI, Integrated Management of Childhood Illness; PHC, primary health centres; PO, pulse oximetry.

Africa. In Papua New Guinea, the prevalence of severe cases using IMCI+PO was 8.3% among 1663 outpatient children aged 3–27 months seen in PHCs in 2019.[37] Elsewhere, it was the prevalence of severe pneumonia using IMCI+PO that was mainly reported. For instance, McCollum *et al* reported a community-based prevalence of severe pneumonia of 8.1% in Bangladesh in 2023.[38] In Ethiopia, this prevalence was 15.9%.[39] Our estimates of the prevalence of severe cases fall within these previous estimates.

The significant heterogeneity observed in the prevalence of severe cases across countries can be explained by various structural and individual factors. First, access to care is affected by the out-of-pocket payment policies in place in each country, as demonstrated elsewhere.[32] Burkina Faso and Niger, for example, provide free healthcare policy for all children under 5 years.[40 41] We hypothesise that this policy has partly facilitated an earlier access to care for sick children, which may explain the lowest prevalence of severe cases in these countries. Mali and Guinea apply a partial free healthcare policy for children under five, targeting only four diseases (malaria, malnutrition, HIV and tuberculosis).[42–44] By delaying care, these diseases contribute to higher observed prevalence of severe cases among sick children attending IMCI consultations. There, parents only go to the PHC when they cannot control danger signs at home. In Mali, they also turn to traditional practitioners, and in Guinea, they turn to private facilities or pharmacies, which delays treatment and worsens the children's condition.[45] Second, geographical difficulties, such as rugged terrain or waterways in Guinea and long distances in Mali, are real obstacles to accessing care for populations. This may explain the median 2-day delay between the onset of symptoms and attendance at a PHC, reaching 3 days in Guinea. In contrast, the proximity of PHCs in Niamey may explain the lower prevalence of severe cases in Niger.[34] Third, the IMCI disease management classification protocols could have played a role. Although all countries have adopted the 2014 IMCI guidelines proposed by the WHO,[11 12] there are nevertheless differences between countries that could explain the high prevalence of severe cases observed in Guinea. There, 'chest indrawing' is considered a sign of severity, whereas in Mali, Burkina Faso and Niger, it classifies children as moderate. We also found that using paper-based IMCI was an independent factor associated with identifying severe cases +41% more often than electronic IMCI. The electronic tool facilitates a systematic and holistic assessment of child health, eliminating the possibility of IMCI headings being omitted and ensuring a more accurate diagnosis, as reported elsewhere.[46] In contrast, the use of the paper format, given the number of documents that need to be filled in manually, may increase the risk of clinician error

when assessing child health, resulting in overestimation of severity.

Using routine PO, we estimated the overall prevalence of severe hypoxaemia (SpO_2 <90%) in all sick children (excluding simple non-respiratory cases) attending IMCI consultations at AIRE PHCs to be around 0.9% (95% CI 0.8 to 1.1). This estimate is consistent with those from other studies conducted in outpatient clinics in Papua New Guinea in 2019[37] and Uganda in 2022.[25] However, it was consistently lower than in other studies that have estimated the prevalence in specific subgroups, such as those with severe pneumonia, severe malaria or other severe childhood illnesses. These studies found prevalence rates of 5.7% in 2013 and 8.3% in 2017 in Malawi,[27 47] 27.9% in Mozambique,[48] and between 5.9% and 62.5% according to systematic reviews.[49] Subhi *et al* estimated a prevalence rate of 13.3% in 2009,[21] and Rahman *et al* found a rate of 31%.[50] In our study, the prevalence of severe hypoxaemia was significantly higher in neonates than in older children. This finding is consistent with the results of other studies: in Malawi, the estimated prevalence of severe hypoxaemia in 2017 was 11.4% in children aged under 5 months, 8.4% in children aged 6–23 months and 4.7% in children aged 24–59 months.[27] Similarly, in Nigeria in 2019, the prevalence was 22.2% in neonates and 10.2% in children under 15 years of age.[23] A literature review reached the same conclusion, stating that one in five neonates was severely hypoxaemic.[21] This higher prevalence in neonates compared with older children could be explained by their immaturity and physiological fragility. The forthcoming analysis of the added value of using PO at primary care for decision-making will be presented elsewhere.

The global adjusted modelling analysis of social health factors associated with disease severity highlights common key factors that allow at-risk populations to be specifically targeted for focused community interventions. These factors were as follows: being a neonate or a child aged 2–5 years, the mother having died, the accompanying person being illiterate and experiencing barriers to care in terms of accessibility and affordability (travel time from home to PHC of more than 30 min, cost). Large families where the mother has other duties and has previously visited the PHC are also more likely to experience delays. These factors confirm previous evidence, including the fragility of neonates,[23] the influence of maternal health, especially maternal death, on child health,[51] and delayed attendance to PHCs due to high distances from homes.[52–58] Free care for children under five has been shown to influence positively accessing care.[59]

Of note, the decision to transfer severe cases identified at PHC to the district hospital was not made systematically, despite the recommendations of the IMCI guidelines. Clinicians preferred to refer neonates' severe cases (46.2% in this age group) than

children aged 2–59 months (29.4%). Several factors may explain this discrepancy. One factor may be the lack of training of HCW at PHCs. As observed in the baseline description of the AIRE research PHCs, there were only nurses, and the IMCI training/refresher courses were not frequent enough given their high turn-over rate.[29] Consequently, their level of qualification and skill was generally low, and despite the implementation of standardised guidelines, such as the IMCI guidelines or protocols for managing specific pathologies, children were not managed properly.[20] In this context, in the absence of other accurate diagnostic tests, except mRDT, HCWs may not necessarily trust the severity outcomes proposed by IMCI symptom-based algorithms. This could lead to severe cases not being referred. Nevertheless, according to ongoing analyses of AIRE data, although low, the proportion of severe cases with a referral decision and their outcome has improved with the use of the PO, as reported in other studies.[30 35 60] Finally, the parents' fear of unaffordable expenses could also have influenced the HCW's decisions not to refer to hospital. This could also be linked to other major challenges (geographical barriers and security issues) reported elsewhere.[30 31]

Our study has several limitations. First, our definition of severe cases was based on severity criteria according to the IMCI guidelines, which incorporate SpO_2 values. These guidelines are symptom based, complex, imperfect and largely operator dependent. This can therefore lead to inaccurate diagnoses of severe cases, since consultations are carried out without aetiological diagnostic tools other than mRDT. In addition, slight differences exist in the adaptation of the WHO-proposed version in each country, particularly with regard to the respiratory disease block in Guinea. The differences in the application of the IMCI guidelines are a key factor to consider when comparing the results between countries. Nevertheless, the standardised inclusion criteria and classification procedures used by the MCI provide reliable estimates of severe cases and their correlates within each country. Another limitation concerns the representativeness of the severe cases included in our study, which may be skewed, as sicker children may be brought to PHCs at night and at weekends. During the data collection period, our research teams were only present on site during working hours, and not at night, at weekends or on public holidays, and also sometimes for security reasons in Mali and Burkina Faso. This selection bias may have led to an underestimation of the prevalence of severe illnesses. To investigate this potential bias further, we conducted an additional study describing the care pathway through PHC level or other itineraries of critically ill children aged 0–5 years arriving at AIRE district hospitals in the four intervention countries.[45]

One of the strengths of our study is that the data, which were collected on a reasonable sample size, were standardised between countries and of good quality, with very few missing data overall. This enabled us to compare results between countries. Our study therefore provides original estimates of ambulatory care at the peripheral level of the healthcare system, whereas most of the existing literature focuses on hospitalised children. Our data are useful for assessing the quality of care for sick children at the primary healthcare level in these West African countries, and for informing national policies. They are also useful for the ongoing analysis of the added value of integrating PO within IMCI guidelines in this context. This will be the subject of a specific paper.

CONCLUSION

This study highlights the high prevalence of severe cases identified at primary care level through the routine use of the PO integrated within IMCI in four West African countries, particularly among neonates. The prevalence of severe cases varied between countries. Although not all the structural and social health factors explaining the heterogeneity in severe illness prevalence were captured, the vulnerability of neonates and children exposed to their mother's death, household illiteracy and accessibility challenges in reaching PHCs was highlighted. Furthermore, clinical decisions regarding transfers to hospital for appropriate care did not meet the needs of all severely ill children. These results underscore the need for concerted action to improve accessibility and care management for severe cases at the primary care level, in order to have a positive impact through the universal use of PO and save lives.[33] This represents a considerable challenge for West African healthcare systems in achieving Sustainable Development Goal 3.

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Competing interests VR is a member of the Editorial Board of the journal BMJ Global Health. He was not involved in the peer- review or handling of the manuscript. All other authors have no competing interest to declare.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Patient consent for publication Consent obtained from parent(s)/guardian(s).

Ethics approval This study involves human participants. The AIRE research protocol, the information notice (translated in vernacular languages), the written consent form and any other relevant document have been submitted to each national ethics committee, to the Inserm Institutional Evaluation Ethics Committee (IEEC) and to the WHO Ethics Review Committee (WHO-ERC). All the aforementioned ethical committees reviewed and approved the protocol and other key documents (Comité d'Ethique pour la Recherche en Santé (CERS), Burkina Faso n° 2020–4-070; Comité National d'Ethique pour la Recherche en Santé (CNERS), Guinea n° 169/CNERS/21; Comité National d'Éthique pour la Santé et les Sciences de la vie (CNESS), Mali n° 127/MSDS-CNESS; Comité National d'Ethique pour la Recherche en Santé (CNERS) Niger n°67/2020/CNERS; Inserm IEEC n° 20–720; WHO-ERC n° ERC.0003364). This study has been retrospectively registered by the Pan African Clinical Trials Registry on 15 June 2022 under the following Trial registration number: PACTR202206525204526. Participants gave informed consent to participate in the study before taking part.

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