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Added value of routine pulse oximetry use within Integrated Management of Childhood Illness guidelines in primary care in West Africa: insight from AIRE

Gildas Boris Hedible,[1] Zineb Zair,[1] Sarah Louart ,[2] Solange Ouédraogo Yugbaré,[3] Abdoul Aziz Diakite,[4] Ibrahima Sory Diallo,[5] Hannatou Souleymane Abarry,[6] Florian Triclin,[7] Marine Vignon,[8] Franck Lamontagne ,[9] Valery Ridde ,[10] Valeriane Leroy ,[1] for the AIRE Research Study Group

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For numbered affiliations see end of article.

Correspondence to
Dr Valeriane Leroy;
valeriane.leroy@inserm.fr

ABSTRACT

Background Integrated Management of Childhood Illness (IMCI) guidelines, used alone, fail to reliably identify severe hypoxaemia (SpO_2<90%), a predictor of mortality in children under five. The AIRE (Améliorer l'Identification des Détresses Respiratoires chez l'Enfant; in English, Improving Identification of Respiratory Distress in Children) operational research project introduced routine use of pulse oximetry (PO) within IMCI consultations in Burkina Faso, Guinea, Mali and Niger. We estimated the added value of incorporating PO within IMCI (IMCI+PO) for improving the diagnosis and subsequent management of severe hypoxaemia in primary healthcare centres (PHCs).

Methods All children aged 0–59 months attending IMCI consultations were eligible for SpO_2 measurement, except those 2–59 months classified as simple non-respiratory cases using IMCI. Monthly aggregated data were collected from 202 AIRE PHC's through a cross-sectional study to estimate the added value of PO within IMCI in diagnosing severe cases (SCs) which should be referred. The added value was defined as the number of additional IMCI SCs with severe hypoxaemia, diagnosed using IMCI+PO, divided by the number of SCs diagnosed using IMCI alone. In a subset of 16 PHCs, we conducted a 14-day cohort follow-up for SCs. We analysed their management and mortality according to hypoxaemia status.

Results Of the 514 901 IMCI consultations between June 2021 and December 2022, 74.2% were eligible for PO use. Of those, 5.4% were SCs diagnosed using IMCI+PO. The added value of PO was +4.9% (+962 SCs; 95% CI 4.6% to 5.2%). This was similar for all countries except Guinea (+0.9%). Healthcare workers' referral decisions were significantly higher for SCs with severe hypoxaemia (74.5%) than for those without (22.2%), p value <0.0001. In the research PHCs, the 142 SCs with severe hypoxaemia were significantly more likely to be referred and admitted to hospital, although their survival rates were similar. However, oxygen therapy remained suboptimal.

Conclusion At PHC level, PO improves the diagnosis of SCs with severe hypoxaemia and is associated with improved management. However, subsequent care in these settings remains challenging.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Severe hypoxaemia (SpO_2<90%) among sick children under five has been estimated in previous meta-analyses as comprising 13% of children with WHO-defined pneumonia.
⇒ The condition also commonly presents in non-respiratory illnesses.
⇒ The condition is a life-threatening event necessitating urgent oxygen therapy, which would normally be provided within hospital care.
⇒ Even when the 2014 Integrated Management of Childhood Illness (IMCI) guidelines are used, severe hypoxaemia is often undiagnosed because pulse oximetry (PO) use is often not implemented within primary care in low-income settings, despite being recommended in respiratory cases.

Trial registration number PanAfrican Clinical Trial Registry (PACTR202206525204526).

BACKGROUND

Hypoxaemia, low blood oxygen levels, is a common sign of severe illness among sick children seen at outpatient and inpatient levels. It is particularly seen in children under five with acute respiratory diseases, but also non-respiratory diseases in resource-limited settings (RLS).[1–5] A high prevalence of severe hypoxaemia (SpO_2<90%), reaching 22% in neonates and 10% in children under five in 12 Nigerian hospitals, has been reported.[3] In children under five attending Integrated Management of Childhood Illness (IMCI) consultations at primary healthcare centres (PHCs), the prevalence of severe hypoxaemia ranged from 1.3% among all children under five in Uganda[4] to 22.6% among children with

WHAT THIS STUDY ADDS

⇒ The AIRE (Améliorer l'Identification des Détresses Respiratoires chez l'Enfant; in English, Improving Identification of Respiratory Distress in Children) project took place in four West African countries (Burkina Faso, Guinea, Mali and Niger).
⇒ The routine use of PO into IMCI was implemented among all children under five at the primary care level, except those aged 2–59 months classified with IMCI as simple non-respiratory cases.
⇒ Among children eligible for PO use, 5.4% were severe cases, of whom 15.3% were severely hypoxaemic.
⇒ The added value of PO use in diagnosing additional severe cases of severe hypoxaemia that would be undiagnosed using IMCI alone was estimated at 4.9% for the four AIRE countries.
⇒ This effect was similar in all countries, except in Guinea.
⇒ Healthcare workers' decisions around hospital transfer, hospitalisation and oxygen therapy rates were significantly higher for children with severe hypoxaemia than for those with moderate or without hypoxaemia.
⇒ Similar results were observed for additional severe cases.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ PO use at the primary care level improves the diagnosis of severe hypoxaemia and is associated with improved healthcare management.
⇒ However, proper management of severe cases remains challenging in these settings, particularly regarding access to oxygen therapy.
⇒ We provide evidence for decision-makers to consider scale-up of the routine use of POs at the primary care level in resource-limited settings, such as in West Africa.
⇒ Our findings could inform the revision of IMCI guidelines at national, regional and international levels.

WHO-defined pneumonia in Malawi.[6] The prevalence of severe hypoxaemia among sick children under five with WHO-defined pneumonia in RLS has been estimated at 13% in a meta-analysis,[1] and at 15% using modelling.[7] In 2025, a meta-analysis conducted in RLS reported a pooled prevalence of severe hypoxaemia among patients in health facilities of 24.5% (95% CI 19.9% to 29.4%) for neonates, and 12.1% (95% CI 10.0% to 14.4%) for children aged 1 month to 17 years.[5]

Hypoxaemia is a strong predictor of child mortality, with mortality risk increasing with the severity of hypoxaemia. Mortality risks remain elevated even for moderate hypoxaemia (SpO_2 from 90% to ≤93%).[1 5 7–9] This condition requires urgent diagnosis and management with oxygen therapy. However, severe hypoxaemia can still be silent, poorly predicted by clinical signs and the predictive value of clinical signs varied across ages and respiratory and non-respiratory conditions.[1 10] At primary care level, poor identification of severe cases (SCs) of pneumonia and under-referral to hospital for further management are contributing factors to high levels of child mortality,[11 12] reaching 71 per 1000 live births in 2023 in sub-Saharan Africa.[13] There, many deaths result from combined factors: delayed care-seeking by families, poor-quality care due to a lack of skilled healthcare workers (HCWs),[14] a lack of aetiological diagnostic tools[15] leading to the misdiagnosis of non-specific IMCI symptoms, weak referral systems and inappropriate treatment.

Pulse oximeters (PO), which measure oxygen saturation in the peripheral blood (SpO_2), are simple, non-invasive, reliable, life-saving tools for identifying children with hypoxaemia and are also used in monitoring oxygen therapy.[16 17] Since 2014, the WHO IMCI guidelines have only recommended the use of PO, if available, for sick children with respiratory signs, with hospital referral, if SpO_2<90%.[18 19] WHO 2016 guidelines for use of supplemental oxygen state that the SpO_2 threshold for initiating oxygen therapy is 90%.[20 21] Progressively, POs have become an essential tool for identifying severe hypoxaemia with applicability in properly indicating and monitoring oxygen therapy in paediatric hospital care, as well as for triaging children in emergency rooms.[21] It is also useful for risk stratification according to the level of hypoxaemia in hospital and primary care settings.[4 22] In RLS, PO availability is limited to hospital settings—specifically, paediatrics, intensive care and emergency wards. However, PO is generally not available within primary care level, despite WHO recommendations for its use for respiratory cases.[4 22–24] Although POs seem to be usable by HCWs as part of care for children under five in a variety of RLS,[17 25–29] their introduction and adoption into routine clinical practice remain challenging at both primary care and at hospital levels.[17]

There is little evidence on the role attributable to PO use in screening and managing outpatient children at primary care levels in sub-Saharan Africa, and particularly in West Africa. In this paper, we estimated the added value of routinely using PO within IMCI, as compared with IMCI alone, in West African sick children under five at primary care level. The aim was to improve the diagnosis of SCs with severe hypoxaemia; we also assessed subsequent management by hypoxaemia severity.

METHODS

The AIRE project

In 2021, the AIRE project (Améliorer l'Identification des Détresses Respiratoires chez l'Enfant; in English, Improving Identification of Respiratory Distress in Children) established the routine use of PO within IMCI guideline implementation, as part of decentralised primary care across four West African countries: Burkina Faso, Guinea, Mali and Niger.[30] The aim was to improve the diagnosis and appropriate management of sick children, aiming to improve HCWs' decisions to refer to hospital and provide oxygen therapy for cases of severe hypoxaemia.[30] The research component of AIRE aimed to provide evidence on how PO use within IMCI works as part of routine care; for which patients it works, why and in what contexts, to guide public health decisions around its introduction at the national level. Several AIRE analyses have already been reported, namely those relating to the context of PO introduction,[24] the acceptability of

PO use and its adoption[29 31] and the outcomes in children.[32–34]

Study sites

The AIRE operational research study was implemented in two health districts within each country, covering 202 urban and rural PHCs and their eight referral district hospitals, with approval from the national health authorities. All PHCs were considered as operational sites from which to collect aggregated health data. 16 research PHCs (four per country) out of the 202 were selected as research sites to provide additional individual health data.[30] All AIRE research PHCs were located at an altitude of less than 2500 m, and are described elsewhere.[24]

Criteria for the use of PO and AIRE study procedures

All children under five attending IMCI consultations at all PHCs were eligible for the routine use of PO, except those aged 2–59 months classified as simple cases by IMCI and without any respiratory signs, such as cough or breathing difficulties. The same model of PO (Acare Technology, Taiwan; AH-M1 S0002033) with specific probes for children and newborns was introduced. Training on the use of PO and refresher training on IMCI were provided prior to the project launch, and implementation was supervised throughout the study period.[30]

POs were used after IMCI classification had already taken place, in accordance with generic WHO IMCI guidelines from 2005, the revisions from 2014 specifically for pneumonia,[18 19 35] and also the revised guidelines for neonates from 2019.[36] Some country-specific features for the definitions of severe pneumonia, severe malaria and severe anaemia for children aged 2–59 months of the IMCI guideline are detailed elsewhere.[37] All children were screened by HCWs using their national IMCI algorithms, then PO was used to classify and manage them based on their disease severity into three groups: green for simple cases (going back home), yellow for moderate cases (observed and treated at PHCs, then at home) and red for SCs. According to standard care guidelines, all those diagnosed as IMCI SCs or with confirmed severe hypoxaemia (SpO_2<90%) regardless of their IMCI classification at PHC should be referred to the district hospital, and those with severe hypoxaemia should receive urgent oxygen therapy.

Study design and inclusion criteria

To assess the added value of PO implemented within the AIRE project, we summarised the outcomes based on two study designs.[30] From June 2021 to December 2022, cross-sectional surveys were repeated monthly in all AIRE PHCs. The aggregated data collected were used to estimate the added value of PO in detecting severe hypoxaemia cases, as indicated above.[30] From June 2021 to June 2022, all children under five, eligible for the use of PO were enrolled in a cross-sectional study in the 16 research PHCs, provided that at least one caregiver gave written consent. Only those classified as SCs were then included in a 14-day prospective cohort after their IMCI consultation, to document their subsequent care management and mortality (online supplemental figure 1).

Data collection

Monthly routine aggregated health indicators collected at all PHCs were as follows: number of IMCI consultations, number of IMCI consultations for children eligible for PO use, number of IMCI consultations with effective use of PO, number of SCs diagnosed with or without severe hypoxaemia and number of hospital referrals decided by the HCW. These aggregated health data were extracted from routine activities and collected over the entire data collection period. The integrated e-Diagnostic Approach implemented in Burkina Faso and in the Markala health district in Mali has digitised the IMCI guidelines for use by HCWs on tablets.[38]

For the 16 research PHCs, additional specific routine registry data were extracted on age category, sex and respiratory conditions at IMCI consultations. Individual data, collected by AIRE research assistants for the children enrolled were sociodemographic data, clinical data about IMCI consultation, including the use of PO, SpO_2 level, decision of hospital referral and at hospital for those who were admitted, data about PO use at admission, patterns of care (oxygen therapy) and the vital status at day-14. REDCap software was used for data collection and monitoring.

Definitions

IMCI+PO SCs were defined as either a child diagnosed as an IMCI SC (red IMCI case) using the IMCI classification, or as an additional SC for a child initially classified as non-SC (simple or moderate) using IMCI alone but presenting with an SpO_2<90% after the use of PO. Severe hypoxaemic non-additional cases were children presenting with severe hypoxaemia but who were also initially classified as SCs using IMCI alone.

Let us consider A as the number of SCs using IMCI alone (the reference method), and B as the total number of SCs using IMCI+PO (online supplemental table 1). B–A represents the number of additional SCs with severe hypoxaemia that were clinically undiagnosed using IMCI alone. The added value of PO within IMCI for improving the diagnosis of SCs is defined as (B–A)/A, expressed as a percentage with its 95% CIs.[39] The adequate care management of severe hypoxaemic cases was defined as those involving actual HCWs' decision to refer, hospital admission and oxygen therapy.

Statistical analysis

We first described the aggregated data from the 202 AIRE PHCs overall and by country, by estimating among children under five eligible for PO use, the proportions of (1) PO uptake, (2) SCs using IMCI alone (before PO use), (3) additional severe hypoxaemic cases after using

PO and (4) all SCs diagnosed combining IMCI+PO. We computed the added value of PO integrated into IMCI for improving the diagnosis of SCs, as defined above. Then, we compared the proportions of HCWs' hospital referral decisions at PHCs for SCs with severe hypoxaemia and those without severe hypoxaemia, allowing us to assess the risk difference in improving the HCWs' referral decision using PO. A similar analysis was also run for the 16 research PHCs.

Second, to further analyse the added value of the use of PO, and using the individual data from children enrolled in the 16 research PHCs, we described and compared the care pathways from primary care (ie, HCWs's decision to refer to hospital, hospital admission, SpO_2 measured at admission and oxygen therapy) and the day-14 mortality rate according to hospitalisation status for: (1) SCs without severe hypoxaemia versus those with severe hypoxaemia diagnosed at PHC and (2) among those with severe hypoxaemia, the additional SCs versus non-additional ones. We also compared sociodemographic and clinical characteristics of additional SCs to non-additional ones among all children with severe hypoxaemia. Similarly, we described the complete cascade of adequate care management, including the following sequences: decision of referral for all children diagnosed with severe illness using IMCI+PO at PHC, hospital admission for those referred, oxygen therapy at hospital for those with severe hypoxaemia and their day-14 mortality outcomes. Categorical data were described with proportions with their 95% CI and compared using Pearson χ^2 or Fisher's exact tests. Means were compared using Student's t-test, and medians using Wilcoxon test.

Finally, we explored the factors associated with the adequate care management of severe hypoxaemic cases, defined as those involving actual HCWs' decision to refer, hospital admission and oxygen therapy. This outcome assessed at the single time point of day-14 can be interpreted as the relative risk of being adequately managed using a full explanatory modified Poisson regression model with robust SEs[40] adjusted on age, sex, country and the following relevant variables: ability for the caregiver to read or write, whether or not the caregiver has an income-generating activity, the travel time from home to PHC, the consultation time since the onset of symptoms, being defined as a respiratory IMCI case and being an additional SC. We reported the adjusted relative risk (aRR) with its 95% CI. All analyses were considered statistically significant with p value less than 0.05. R software V.4.3.0 was used for analyses.

Patient and public involvement

Patient representatives were not involved in the analysis plan, interpretation or dissemination of the results. Patient representatives did not contribute to the writing or editing of this manuscript.

RESULTS

Added value of PO in improving diagnosis and referral decisions

For all 202 PHCs, using aggregated data

In the 202 AIRE PHCs, monthly trends of median values of PO use show that it reached and exceeded 80% for eligible children in 3 months.[29] Overall, 514 901 children under five attended IMCI consultations over the 18-month study period. Among these, 382 171 (74.2%) were eligible for PO use, of whom 356 805 (93.4%) had an SpO_2 measurement (table 1). Among children eligible for PO, the rate of SCs identified using IMCI+PO was estimated at 5.4% (2.2% in Niger, 4.1% in Burkina Faso, 7.0% in Guinea and 20.9% in Mali). Among the 20 743 SCs diagnosed using IMCI+PO, 3183 (15.3%) were severely hypoxaemic, of whom 962 (30.2%) were additional SCs that would have been missed using IMCI alone. The added value of the routine use of PO within IMCI guidelines, for diagnosing additional SCs of severe hypoxaemia, estimated overall for the four countries, was at +4.9% (95% CI 4.6% to 5.2%). These results were similar for Burkina Faso (+6.1%), Mali (+6.2%) and Niger (+4.5%), but significantly lower in Guinea (+0.9%) (p<0.001).

After IMCI+PO consultations, HCW decided to refer for 30.2% of the SCs overall. However, this varied between countries, with a significantly higher proportion in Niger, where HCWs decided on referral for 82.7% of SCs, as compared with other countries (p<0.001). Overall, the rate of HCWs' referral decisions for SCs with severe hypoxaemia was 74.5%; this was significantly higher than for SCs without severe hypoxaemia (22.2%; p<0.001). The relative improvement in the decision to refer between those with and without severe hypoxaemia was +52%, ranging from +24.9% in Niger to +75.2% in Guinea (table 1).

For 16 research PHCs, using both aggregated and registry data

Overall, 39 360 children under five attended IMCI consultations in the 16 research PHCs over the inclusion period (online supplemental figure 2). Using aggregated data in a similar way to the above analysis, 31 600 (80.3%) were eligible for PO use, of whom 9.8% were classified as SCs using IMCI alone (table 2). The use of PO in 30 374 children (96.1%) diagnosed 62 additional cases of severe hypoxaemia, yielding an added value of +1.9% (95% CI 1.5 to 2.5%), significantly lower than for all AIRE PHCs. However, these 62 additional SCs represented 29.0% of all cases of severe hypoxaemia and would have been missed using IMCI alone. The added value for all 16 research PHC was also similar between Burkina Faso (+0.9%), Mali (+3.2%) and Niger (+2.9%), but significantly lower in Guinea (+0.3%; p<0.001). Similarly, the HCW's rate of decision to refer for SCs with severe hypoxaemia was 59.4%, and this was significantly higher than for SCs without severe hypoxaemia (16.7%; p<0.001) with a relative difference of +42.7%, varying significantly from +2.1% in Niger to +63.7% in Guinea.

Table 1 Added value of using routine PO integrated within IMCI guidelines in improving the diagnosis of additional severe cases (severe hypoxaemia with SpO_2<90% IMCI-undiagnosed) and in HCWs' decision to refer according to severe hypoxaemia for the 382 171 children under five eligible for PO use in the 202 primary health centres, overall and by country; AIRE project, June 2021–December 2022 (aggregated registry data, n=514 901)

	Burkina Faso	Guinea	Mali	Niger	Total	P value*
All children under five attending IMCI consultations	N=250 297	N=79 571	N=39 550	N=145 483	N=514 901	
Children eligible for PO use, n (%)	182 626 (73.0)	59 252 (74.5)	31 765 (80.3)	108 528 (74.6)	382 171 (72.2)	<0.001
Children with uptake of PO among those eligible, n (%)	161 380 (88.4)	56 675 (95.7)	30 676 (96.6)	108 074 (99.6)	356 805 (93.4)	<0.001
Diagnosis of additional severe cases						
Severe cases diagnosed using IMCI alone (A) among children eligible for PO use, n (%)	7125 (3.9)	4112 (6.9)	6258 (19.7)	2286 (2.1)	19 781 (5.2)	<0.001
Severe cases diagnosed using IMCI+PO (B) among children eligible for PO use, n (%)	7558 (4.1)	4147 (7.0)	6648 (20.9)	2390 (2.2)	20 743 (5.4)	<0.001
Severe hypoxaemia diagnosed using PO (C) among all severe cases (C/B), n (%)	889 (11.8)	580 (14.0)	861 (13.0)	853 (35.7)	3183 (15.3)	<0.001
Additional severe cases after PO use (severe hypoxaemia among IMCI non-severe cases; (B–A)) among all severe hypoxaemia cases ((B–A)/C), n (%)	433 (48.7)	35 (6.0)	390 (45.3)	104 (12.2)	962 (30.2)	<0.001
Added value of PO in diagnosing additional severe cases; ((B–A)/A) (%) (95% CI)	+6.1 (5.5 to 6.7)	+0.9 (0.6 to 1.2)	+6.2 (5.6 to 6.9)	+4.5 (3.7 to 5.5)	+4.9 (4.6 to 5.2)	
HCW's decision to refer after using IMCI+PO						
HCW's decision to refer among all severe IMCI+PO cases, n (%)	1446 (19.1)	1456 (35.1)	1389 (20.9)	1976 (82.7)	6267 (30.2)	<0.001
HCW's decision to refer in severe IMCI+PO cases without severe hypoxaemia, n (%)	1030 (15.4)	877 (24.6)	856 (14.8)	1134 (73.8)	3897 (22.2)	<0.001
HCW's decision to refer in severe IMCI+PO cases with severe hypoxaemia, n (%)	416 (46.8)	579 (99.8)	533 (61.9)	842 (98.7)	2370 (74.5)	<0.001
Relative difference in improving the HCW's decision to refer severe cases with severe hypoxaemia compared with those without severe hypoxaemia (%)	+31.4	+75.2	+47.1	+24.9	+52.3	<0.001

*χ^2 test. See definition of added value in the Methods section.
AIRE, Améliorer l'Identification des Détresses Respiratoires chez l'Enfant (Improving Identification of Respiratory Distress in Children); HCW, healthcare worker; IMCI, Integrated Management of Childhood Illness; PO, pulse oximetry; SC, severe case.

Care management of SCs

In the 16 research PHCs, a total of 15 836 children (99.6% of those included in AIRE study) were analysed. Of them, 12.6% (N=1998) were diagnosed as SCs and followed up until day-14, including 142 (7.1%) with severe hypoxaemia (online supplemental figure 2). Of those, 27 (19.0%) were additional SCs diagnosed subsequent to PO use, all initially diagnosed as moderate IMCI cases (online supplemental table 2). Their sociodemographic and clinical characteristics were similar to those of the 115 initially diagnosed as SCs using IMCI (online supplemental table 3).

Out of all included SCs, 463 (23.2%) were hospitalised with a median delay of 1 day (range: 0–1 day). The hospitalisation rate was significantly higher for hypoxaemic SCs diagnosed at PHC level, 82.4% (N=117), while the rate for those non-hypoxaemic cases was 18.6% (N=346; p<0.001). Median times to hospitalisation, among the 142 hypoxaemic SCs were similar between additional SCs and non-additional SCs (online supplemental table 4). At hospital admission, SpO_2 was controlled in 91.8% of cases (table 3). Severe hypoxaemia was confirmed in 75 cases (16.2% of the 463): 40.2% of the 117 hypoxaemic SCs identified at PHC versus 8.1% of the 346 without severe

Table 2 Added value of using routine PO integrated within IMCI guidelines in improving the diagnosis of additional severe cases (severe hypoxaemia with SpO_2<90% but IMCI-undiagnosed) and in making HCW's decision to refer according to severe hypoxaemia for the 31 600 children under five eligible for PO use at IMCI consultations in the 16 selected research primary healthcare centres, overall and by country; AIRE project, June 2021–June 2022 (registry data, n=39 360)

	Burkina Faso	Guinea	Mali	Niger	Total	P value*
All children under five attending IMCI consultations	N=8431	N=2658	N=7495	N=20 776	N=39 360	
Children eligible for PO use, n (%)	6032 (71.5)	2561 (96.4)	6634 (88.5)	16 373 (78.8)	31 600 (80.3)	<0.001
Children with uptake of PO, n (%)	5856 (97.1)	2460 (96.1)	6607 (99.6)	15 451 (94.4)	30 374 (96.1)	<0.001
Diagnosis of additional severe cases						
Severe cases diagnosed using IMCI alone (A) among children eligible for PO use, n (%)	211 (3.4)	1159 (45.3)	1385 (20.9)	346 (2.1)	3101 (9.8)	<0.001
Severe cases identified using IMCI+PO (B) among children eligible for PO use, n (%)	213 (3.5)	1164 (45.4)	1431 (21.6)	356 (2.2)	3163 (10.0)	<0.001
Severe hypoxaemia diagnosed using IMCI+PO (C) among all severe cases (C/B), n (%)	9 (4.2)	14 (1.2)	110 (7.7)	74 (20.8)	207 (6.5)	<0.001
Additional severe cases after PO use (severe hypoxaemia among IMCI non-severe cases; (B–A) among all severe hypoxaemia cases ((B–A)/C), n (%)	2 (22.2)	4 (28.6)	46 (41.8)	10 (13.5)	62 (29.9)	0.001
Added value of PO in diagnosing additional severe cases; ((B–A)/A) (%) (95% CI)	+0.9 (0.1 to 3.4)	+0.3 (0.09 to 0.9)	+3.2 (2.3 to 4.2)	+2.9 (1.4 to 5.2)	+1.9 (1.5 to 2.5)	–
HCW's decision to refer after using IMCI+PO						
HCW's decision to refer among all severe IMCI+PO cases, n (%)	25 (11.7)	99 (8.5))	172 (12.0)	321 (90.2)	617 (19.5)	<0.001
HCW's decision to refer in severe IMCI+PO cases without severe hypoxaemia, n (%)	15 (7.3)	89 (7.7)	133 (10.1)	253 (89.7)	494 (16.7)	<0.001
HCW's decision to refer in severe IMCI+PO cases with severe hypoxaemia, n (%)	6 (66.6)	10 (71.4)	39 (35.5)	68 (91.8)	123 (59.4)	<0.001
Relative difference in improving HCW's decision to refer severe cases with severe hypoxaemia compared with those without severe hypoxaemia (%)	59.3	63.7	25.4	2.1	42.7	<0.001

*χ^2 test. See definition of added value in the Methods section.
AIRE, Améliorer l'Identification des Détresses Respiratoires chez l'Enfant (Improving Identification of Respiratory Distress in Children); HCW, healthcare worker; IMCI, Integrated Management of Childhood Illness; PO, pulse oximetry; SC, severe case.

hypoxaemia at PHC and newly diagnosed (p=0.001) (online supplemental figure 3). Among these children with severe hypoxaemia confirmed at admission, the rate of provision of oxygen therapy was similar between those who were diagnosed with hypoxaemia at PHC level and those newly diagnosed on hospital admission (83.0% vs 67.8%; p=0.219). Their subsequent day-14 mortality rates were also similar (28.2% vs 36.8%; p=0.715). This trend was similar in other strata according to the confirmed diagnosis of hypoxaemia at hospital admission (table 3). However, day-14 mortality was significantly higher among those who were confirmed as severely hypoxaemic cases at admission, and did not receive oxygen (4/8), compared with those newly diagnosed with severe hypoxaemia at admission who also did not receive oxygen (0/9; p=0.003). Specific findings were observed in Niger, where more SCs were referred by HCW but there were similar rates of severe hypoxaemia at admission for SCs diagnosed without severe hypoxaemia at PHC and those diagnosed with severe hypoxaemia within primary care (p=0.391, online supplemental table 5). From the 463 children hospitalised covering all four countries, 65 SCs (14.0%) hospitalised had moderate hypoxaemia confirmed at entry: 14.5% of the 346 children without severe hypoxaemia at PHC versus 12.8% of the 117 with severe hypoxaemia at PHC (p=0.775). In both groups,

Table 3 Care management (admission to district hospital, confirmation of hypoxaemia at admission, oxygen therapy at admission) and day-14 mortality outcome according to hospital admission status and hypoxaemia confirmation for the 1998 IMCI+PO severe cases enrolled at the 16 AIRE research PHCs, June 2021–June 2022

	All the severe cases diagnosed using IMCI+PO at PHC level N=1998			Severe cases diagnosed with severe hypoxaemia N=142		
Place of care management and SpO_2 value for severe cases	Without severe hypoxaemia at PHC N=1856	With severe hypoxaemia at PHC N=142	P value with vs without hypoxaemia	Additional cases* N=27	Non-additional cases N=115	P value additional vs non-additional
Admitted to hospital, n (%)	346 (18.6)	117 (82.4)	<0.001	20 (74.1)	97 (84.4)	0.326
N=463						
Severe hypoxaemia at entry, n (%)	28 (8.1)	47 (40.2)	<0.001	12 (60.0)	35 (36.0)	0.082
N=75 (16.2%)						
Oxygen therapy, n (%)	19 (67.8)	39 (83.0)	0.219	11 (91.6)	28 (80.0)	0.629
Death at day 14, n (%)	7 (36.8)	11 (28.2)	0.715	2 (18.1)	9 (32.1)	0.633
No oxygen therapy, n (%)	9 (32.2)	8 (17.0)	0.219	1 (8.0)	7 (20.0)	0.629
Death at day 14, n (%)	0 (0.0)	4 (50.0)	0.003	0 (0.0)	4 (57.1)	1†
Moderate hypoxaemia at entry, n (%)	50 (14.5)	15 (12.8)	0.775	2 (10.0)	13 (13.4)	0.962
N=65 (14.0%)						
Oxygen therapy, n (%)	10 (20.0)	3 (20.0)	1†	1 (50.0)	2 (15.4)	0.371†
Death at day 14, n (%)	1 (10.0)	2 (66.6)	0.107†	1 (100.0)	1 (50.0)	1†
No oxygen therapy, n (%)	40 (80.0)	12 (80.0)	1	1 (50.0)	11 (84.6)	0.371†
Death at day 14, n (%)	3 (7.5)	1 (8.3)	1†	0 (0.0)	1 (9.1)	1†
No hypoxaemia at entry, n (%)	241 (69.6)	44 (37.6)	<0.001	6 (30.0)	38 (39.2)	0.604
N=285 (61.6%)						
Oxygen therapy, n (%)	9 (3.8)	7 (15.9)	0.004	2 (33.3)	5 (13.2)	0.512
Death at day 14, n (%)	3 (33.3)	2 (28.5)	1†	0 (0.0)	2 (40.0)	1†
No oxygen therapy, n (%)	232 (96.2)	37 (84.1)	0.004	4 (66.6)	33 (86.8)	0.512
Death at day 14, n (%)	16 (6.9)	3 (8.1)	1†	0 (0.0)	3 (9.1)	1†
No SpO_2 measurement at entry, n (%)	27 (7.8)	11 (9.5)	0.726	0 (0.0)	11 (11.4)	0.207*
N=38 (8.2%)						
Oxygen therapy, n (%)	1 (3.7)	0 (0.0)	1†	0 (0.0)	0 (0.0)	NA
Death at day 14, n (%)	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	NA
No oxygen therapy, n (%)	22 (81.5)	11 (100.0)	1†	0 (0.0)	11 (100.0)	NA
Death at day 14, n (%)	4 (18.2)	9 (81.8)	0.001	0 (0.0)	9 (81.8)	NA
Deaths at day 14 among severe cases admitted to hospital, n (%)	36 (10.4)	32 (27.3)	<0.001	3 (15.0)	29 (29.9)	0.277
Not admitted to hospital n (%)	1510 (81.4)	25 (17.6)	<0.001	7 (25.9)	18 (15.7)	0.326
N=1535						
Oxygen therapy, n (%)	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	NA
Death at day 14, n (%)	22 (1.5)	5 (20.0)	<0.001	1 (14.2)	4 (22.2)	1†
Deaths at day 14 among all severe cases diagnosed at PHC, n (%) N=95	58 (3.2)	37 (26.1)	<0.001	4 (14.8)	33 (28.6)	0.216

Severe hypoxaemia: SpO_2<90%.
*Additional cases are those with severe hypoxaemia undiagnosed using IMCI alone and identified using PO.
†Fisher's exact test use.
AIRE, Améliorer l'Identification des Détresses Respiratoires chez l'Enfant (Improving Identification of Respiratory Distress in Children); IMCI, Integrated Management of Childhood Illness; NA, not applicable; PHC, primary healthcare centre; PO, pulse oximetry; SC, severe case.

20% had received oxygen and no significant difference was observed for day-14 mortality rate (p=0.107).

Of note, 37.6% (44 of the 117 severe hypoxaemias diagnosed at PHC level) were no longer confirmed with hypoxaemia on admission, but presented with severe illness: severe pneumonia, very severe febrile illness, severe acute malnutrition with complications or severe malaria. Of these 44 children, 7 (15.9%) received oxygen therapy, as compared with 9 (3.8%) of the 241 without hypoxaemia measured at PHC (p=0.004). Finally, 38 children (8.2%) had no SpO_2 measurement performed at admission, 11 (9.5%) of those with severe hypoxaemia at PHC versus 22 (7.8%) of those without severe hypoxaemia (p=0.726). None of the 11 severely hypoxaemic children had received oxygen and 9 have died by day 14 (81.8%) (median delay on the first day of admission).

Overall, 1535 (76.8%) SCs were not hospitalised, of whom 81.4% were not hypoxaemic and 17.6% had severe hypoxaemia diagnosed at PHC. None of them received oxygen therapy. The mortality rate at day 14 was significantly higher among those diagnosed with severe hypoxaemia at PHC (20%) compared with those without (1.5%) (p<0.001), but with a similar mortality rate to that seen at day 14 among those children diagnosed and confirmed with severe hypoxaemia at hospital admission and who received oxygen therapy (28.2%).

Cascade of care management subsequent to hypoxaemia from PHCs to hospital

Table 4 shows the complete cascade of care (HCW's decision to refer, hospital admission and oxygen therapy) for the 1998 SCs included, stratified according to severe hypoxaemia diagnosed at the 16 research PHCs. For all the steps of the cascade of care, the overall management of the 142 SCs with severe hypoxaemia was significantly improved compared with the 1856 SCs without severe hypoxaemia (p<0.001): HCW's decision to refer at PHC (84.5% vs 27.1%), hospital admission for those referred (97.5% vs 68.7%) and oxygen therapy for those hospitalised (41.9% vs 11.2% although not expected to receive oxygen) (online supplemental figure 4). However, we did not see a significant difference in mortality outcome at day-14 between cases with severe hypoxaemia at PHC (28.2%) compared with those without (30.6%); p=0.99.

Among the 142 severely hypoxaemic cases included in the 16 research PHCs, additional cases had similar referral rates to non-additional cases. Among the 27 additional cases, 20 (87.0%) of those referred were hospitalised and 14 (70.0%) received oxygen therapy among those admitted (table 4). For the 115 severe hypoxaemic non-additional cases, 97 (84.3%) were referred and all hospitalised and 35 (30.4%) of those received oxygen therapy. Additional SCs hospitalised had significantly greater access to oxygen therapy than severely hypoxaemic non-additional cases, (70.0% vs 30.4%; p=0.003) (table 4). Again, the mortality rate at day-14 did not differ between additional and non-additional cases (p=0.43).

Factors associated with adequate care for severely hypoxaemic children

Factors associated with an adequate care management until receipt of oxygen therapy for the 142 children identified with severe hypoxaemia at the PHC level were explored. The 10 Guinean children were excluded, as none of them were admitted to hospital for oxygen therapy, which made it impossible to analyse their odds of receiving adequate care. For the remaining 132, 49 (37.1%) had adequate care management (table 5). Adjusted on age, sex, respiratory cases, additional SCs, parent' ability to read, income-generating activity of the accompanying person, travel time from home to PHC and country, two factors were significantly associated with an adequate care management for severe hypoxaemias identified at the PHC level: children whose parent

Table 4 Cascade of care (HCW's decision to refer, admission to district hospital, access to oxygen at hospital) and day-14 mortality outcomes for the 1998 severe cases diagnosed using IMCI+PO enrolled at the 16 AIRE research PHCs by severe hypoxaemia status, and for the 142 severe hypoxaemic cases, June 2021–June 2022

	All severe cases diagnosed using IMCI+PO at PHC level N=1998			Only severe cases with severe hypoxaemia (SpO_2<90%) N=142		
Cascade of care for severe cases diagnosed at primary care	Without severe hypoxaemia (SpO_2≥90%)	With severe hypoxaemia (SpO_2<90%)	P value (with vs without hypoxaemia)	Additional cases	Non-additional cases	P value (additional vs non-additional)
	N=1 856	N=142		N=27	N=115	
HCW's decision to refer for severe cases, n (%)	503 (27.1)	120 (84.5)	<0.001	23 (85.2)	97 (84.3)	1
Hospital admission for those referred, n (%)	346 (68.7)	117 (97.5)	<0.001	20 (87.0)	97 (100)	0.004
Oxygen therapy for those admitted, n (%)	39 (11.2)	49 (41.9)	<0.001	14 (70.0)	35 (30.4)	0.003
Death at day 14 for those having received oxygen, n (%)	11 (28.2)	15 (30.6)	0.991	3 (21.1)	12 (34.2)	0.425

AIRE, Améliorer l'Identification des Détresses Respiratoires chez l'Enfant (Improving Identification of Respiratory Distress in Children); HCW, healthcare worker; IMCI, Integrated Management of Childhood Illness; PHC, primary healthcare centre; PO, pulse oximetry.

Table 5 Associated factors of adequate management of severe hypoxaemic cases (including referral, hospital admission and access to oxygen therapy) using an adjusted modified Poisson regression model with robust SEs (N=49/132 children enrolled). The 10 Guinean severe hypoxaemic cases were excluded as none of them were hospitalised. AIRE research project, Burkina Faso, Mali and Niger—June 2021–June 2022.

		Complete care management		Univariate	Multivariate
Variables	Categories	Inadequate N=83	Adequate N=49	RR (95% CI)	aRR (95% CI)
Age (months)	24–59 months	17 (20.5)	12 (24.5)	–	–
	<2 months	51 (61.4)	22 (44.9)	0.73 (0.41 to 1.28)	0.78 (0.45 to 1.38)
	2–23 months	15 (18.1)	15 (30.6)	1.21 (0.68 to 2.13)	0.89 (0.45 to 1.74)
Sex	Female	36 (43.4)	26 (53.1)	–	–
	Male	47 (56.6)	23 (46.9)	0.78 (0.5 to 1.23)	0.79 (0.52 to 1.21)
Ability to read or write of the accompanying	Cannot read or write	73 (88.0)	41 (83.7)	–	–
	Can read or write	10 (12.0)	8 (16.3)	1.24 (0.69 to 2.2)	1.92 (1.01 to 3.66)
Income-generating activity of the accompanying person	No	67 (80.7)	39 (79.6)	–	–
	Yes	16 (19.3)	10 (20.4)	1.05 (0.6 to 1.81)	0.93 (0.53 to 1.63)
Travel time home—PHC	<30 min	51 (61.4)	22 (44.9)	–	–
	≥30 min	32 (38.6)	27 (55.1)	1.52 (0.97 to 2.38)	1.57 (0.96 to 2.58)
Consultation time since the onset of symptoms (days)	≤2	36 (52.9)	24 (61.5)	–	–
	>2	32 (47.1)	15 (38.5)	0.8 (0.47 to 1.35)	-*
Respiratory case	Non-respiratory case	18 (21.7)	12 (24.5)	–	–
	Respiratory case	65 (78.3)	37 (75.5)	0.91 (0.54 to 1.51)	0.97 (0.6 to 1.57)
Additional severe cases diagnosed using pulse oximetry	No	70 (84.3)	35 (71.4)	–	–
	Yes	13 (15.7)	14 (28.6)	1.56 (0.99 to 2.46)	1.08 (0.67 to 1.73)
Country	Niger	28 (33.7)	2 (4.1)	–	
	Burkina Faso	4 (4.8)	6 (12.2)	4 (1.8 to 8.86)	5.47 (2.01 to 14.89)
	Mali	28 (33.7)	34 (69.4)	3.66 (1.91 to 7.01)	3.74 (1.84 to 7.62)

*Not included due to significant correlation with respiratory case.
AIRE, Améliorer l'Identification des Détresses Respiratoires chez l'Enfant (Improving Identification of Respiratory Distress in Children); aRR, adjusted RR; PHC, primary healthcare centre; RR, relative risk; SC, severe case.

could read or write were more likely to receive adequate care compared with those whose parent could not read or write (aRR=1.92; 95% CI 1.01 to 3.66). Children in Burkina Faso (aRR=5.47; 95% CI 2.01 to 14.89) and Mali (aRR=3.74; 95% CI 1.84 to 7.62) were more likely to receive adequate care management than those in Niger.

DISCUSSION

This analysis from the AIRE operational study provides data on the added value of using PO to increase the diagnosis of severe hypoxaemia. We also report on the effects of improved healthcare management for critically ill children under five attending primary care, and managed using IMCI+PO in four West African countries, regardless of respiratory condition. Our results reveal the following specific findings.

First, analysis of aggregated data from a large sample size of over 500 000 IMCI consultations in 202 PHCs over 18 months indicates a very high uptake of PO among eligible children,[29] suggesting its feasibility on a large scale in primary care. Among children eligible for PO use, 5.4% were diagnosed as SCs using IMCI+PO, of whom 15.3% were severely hypoxaemic. Approximately 30% of these severely hypoxaemic children would have been missed using IMCI alone. Thus, the use of PO increased the diagnosis of severe illnesses related to severe hypoxaemia by +4.9%, which would have been missed by IMCI guidelines alone. This effect was consistent across all countries except Guinea, where it was significantly lower (0.9%). This discrepancy is explained by the fact that the Guinean IMCI guidelines already identified a high proportion of severe pneumonia cases, as detailed elsewhere.[33]

Of note, discrepancies were also observed in the estimates of added value for all PHCs (+4.9%) and the 16 research PHCs (+1.9%), which can be explained by the fact that the latter are not representative of all PHCs. The research PHCs were selected based on geographical accessibility, safety for the research teams and to reflect variation in PHC attendance (low, medium or high).[24] Although the added value remains lower in research sites, it should be noted that this is still conservative in relation to all sites.

Second, 30% of all SCs, regardless of the severity of hypoxaemia, and 75% of severely hypoxaemic cases, had HCW's decision to refer. Using PO was associated with a higher chance of HCW decision to refer, with an increase of 52.3% between those with and without severe hypoxaemia diagnosed. These referral rates were much higher than the 1.5% recorded in the baseline assessment of the same sites.[24] This finding is consistent with findings from a realist evaluation conducted within AIRE, which showed that POs increased HCWs' diagnostic confidence and improved decision-making regarding care management.[31] Unfortunately, it should also be noted that not all children with serious illnesses, even hypoxaemic, were transferred to hospital. This highlights the problems in applying IMCI protocols, as well as the difficulties in organising hospital referrals for SCs, which remain challenging in such settings.[37 41 42]

Third, when using individual data from the 16 AIRE PHCs, we observed a consistent and significant improvement in the full cascade of care management (including higher referral decision, hospitalisation and oxygen therapy rates) for the 7% of children diagnosed at PHC with severe hypoxaemia compared with SCs without hypoxaemia. In our study, the main bottleneck in the cascade of care was the low rate of oxygen therapy, reaching only 42% of those admitted with severe hypoxaemia at PHC. Two independent factors were associated with adequate management of severely hypoxaemias at hospital, including oxygen therapy, parents' ability to read and write and living in Burkina Faso or Mali compared with those children living in Niger. This latter result was unexpected, as SCs in Niger were referred to and admitted to hospital more frequently than in other countries, due to closer proximity to hospital and a national 'centimes' policy to support referrals. These findings clearly raise questions around late referrals and suboptimal quality of care in hospitals in Niger. Parental literacy was already described as a positive factor of child health elsewhere.[43]

Fourthly, we also identified some discrepancies between the hypoxaemia levels measured at PHC and district hospital levels, and subsequent management. Not all severe hypoxaemia cases identified at PHC level were confirmed at hospital. There are several explanations. False positive diagnoses of severe hypoxaemia may have occurred, given that the prevalence of severe hypoxaemia is low at population level. Additionally, PO measurement error can range from 0.8% to 3.9%, linked with device performance or operator interpretation.[44 45] This could lead to misclassification at both the PHC and hospital levels. As supervision at hospitals was only provided at the beginning of the project and not during its implementation, measurement errors when using the PO at hospital admission cannot be ruled out. Children with severe hypoxaemia at the PHC and without SpO_2 measurements on admission were probably critically ill and did not survive long enough to be confirmed and receive oxygen, as indicated by their high mortality rate of 81.8%. However, it is worth noting that almost all transferred cases were IMCI SCs requiring hospitalisation for reasons other than severe hypoxaemia alone, as reported elsewhere.[32] Their hypoxaemia status may have improved due to treatment initiated for their underlying condition. For instance, normalised body temperature can increase SpO_2.[46]

Finally, despite an improved cascade of care management of the SCs, there was no difference in the day-14 mortality rate (30.6% vs 28.2%), while this rate was significantly higher in all SCs with severe hypoxaemia than in those without (26.1% vs 3.2%, p<0.001), as we also previously discussed elsewhere.[32]

POs were first used in Africa in primary care settings to screen children with signs of pneumonia in rural Malawi.[25 27] Of the 14 092 children included, 94.1% were successfully screened using PO, which is similar to our study. In Malawi, if the 2014 IMCI guidelines had been applied without PO, 42.0% children with severe hypoxaemia at the PHC would have been considered ineligible for hospital referral.[25] In an Ethiopian cluster randomised trial, the proportion of children diagnosed with severe pneumonia increased significantly from 3.9% (34/876) in the control arm without PO to 15.9% (148/928) in the intervention arm using PO.[47] These studies highlight that the 2014 IMCI guidelines alone fail to identify a substantial proportion of severely hypoxaemic children in children with respiratory signs who are at high risk of death,[22] and support the role of PO in improving their diagnosis and their referral for better management. The PO effect appears to be greater in the above studies than in our estimation. This is because they targeted only IMCI cases of pneumonia, which are at a higher risk of severe hypoxaemia. In contrast, we focused on all children eligible for PO, including those without respiratory symptoms. These children represented 80% of the IMCI children in our study. For comparison, the TIMCI project—a large cluster-randomised controlled trial assessing point-of-care devices, PO and digital clinical decision support algorithms for all sick children in 172 PHCs in India and Tanzania—also reported a high uptake of PO in India, but only a third (neonates) or half (older children) in the Tanzanian sites had a PO measurement due to differences in context and implementation.[48] The prevalence of severe hypoxaemia was lower in the TIMCI study than in the AIRE study: 0.5% versus 3.3% for the neonates, and 0.3% versus 0.8% for older children.[33 48] Our finding indicating improved HCW decision to refer is similar to

the Malawian study described earlier,[25] but this finding does not emerge from the Tanzanian sites of the TIMCI study.[48] The low oxygen therapy rate observed in our study is consistent with that in previous studies.[2 22 49–52]

Overall, our study has several limitations: first, AIRE initially aimed to use a quasi-experimental design, with a 'before and after' comparison component. However, the intended design was disrupted by the COVID-19 pandemic. The design was modified to the current operational study, investigating the consequences of PO deployment on the diagnosis of severe hypoxaemia in sick children at PHCs, their appropriate care management and mortality by day-14. We provide a direct comparison that assesses the number of additional SCs diagnosed using SpO_2 measurement within IMCI, compared with IMCI alone for each child. This shows that PO improves the diagnosis of SCs with severe hypoxaemia. However, due to the design, a counterfactual comparison was not available for assessing the impact of PO use in improving care management outcomes, nor cost-effectiveness. Second, the selection of AIRE intervention health districts and public research PHCs[24] made them not perfectly representative of all PHCs nationally. However, the aggregated data provide reasonable evidence, using a large sample size, to measure the overall added value of PO in improving the diagnostic accuracy of serious illnesses in primary care. Third, there is evidence that certain PO devices may overestimate oxygen saturation levels in children with dark skin tones.[53–55] This bias would have led to underestimates of the added value in diagnosing severe hypoxaemia in this African population; our estimates would therefore be conservative. Finally, the research component of the AIRE project was conducted in 16 PHCs from four countries, with heterogeneity in their context and care practices; these might affect outcomes, particularly in estimating the added value of PO in diagnosis and referral decisions.[24] However, to mitigate this variability, all healthcare professionals were trained and practices were standardised.

Our study also has strengths: few datasets exist in this area with such a large sample size and they also include neonates. Very few studies have examined this clinical topic in the West African context. Individual data collected were comprehensive, and case follow-up was excellent, at 98.6%. Our results provide a valuable contribution to the body of research evidence on the impact of the use of PO in primary care.

We feel that our +4.9% estimate of the added value of PO in improving the diagnosis of SCs may be meaningful enough at the population level in terms of improving overall diagnostic accuracy at primary care, given the high uptake of PO use. Furthermore, this proportion would not place an excessive burden on the healthcare system and would be acceptable to cover in providing appropriate care in resource-limited contexts, particularly with regard to access to oxygen therapy. Nevertheless, our results collectively raise questions about HCW training and the quality of care provided using PO both at the PHC and at the hospital levels.[24 29 31] HCWs will require additional support and training in managing referrals at PHC, and in providing oxygen therapy at hospital when scaling up the use of PO in Africa.

To improve equity, it would be important to investigate the availability of oxygen at PHC level, or in ambulances, to enable the initiation of oxygen therapy and improve the survival rate of non-transferred severe hypoxaemia cases. To our knowledge, several ongoing studies are assessing the introduction of PO into IMCI guidelines in different contexts using mixed-methods approaches.[22 56] Equipping PHCs with PO and oxygen could potentially fill in this gap.[51 57–59] Doing so within primary care in Nigeria has shown an increase in oxygen use for children with hypoxaemia, but this intervention did not improve referral or hospital admission rates.[58] Furthermore, findings from the TIMCI trial are contradictory, as in this study, PO was not found to increase rates of rapid hospitalisation, nor to decrease deaths, nor to have an impact on delayed or non-referred hospitalisations.[48] It is critical to note that the uptake of PO was very low, reaching 37% in those aged 1–59 days and 48% in 2–59 months, in sites in Tanzania. Nevertheless, these findings collectively highlight the health system challenges which must be addressed to optimise the potential benefit of PO, specifically referral barriers, inequitable oxygen access and care quality. Evidence still needs to be strengthened to gain the support of decision-makers and to improve healthcare systems in sub-Saharan Africa.

CONCLUSION

The latest 2024 WHO update on IMCI omits any recommendation around the routine use of PO in primary care, stating that at that time, more evidence was needed.[60] We report a significant added value for routine use of PO within IMCI guidelines for improving the diagnosis of serious illnesses in West African PHC. Our data overall estimate this at 4.9%, which demonstrates the potential usefulness of PO if these additional cases are adequately managed. The use of PO was also associated with an improved overall management of children with severe illnesses and severe hypoxaemia, which could significantly impact infant mortality rates. However, proper management of hypoxaemia remains challenging, especially considering the access and skills needed to provide oxygen therapy. Despite evidence of its potential usefulness, the scarcity of PO availability in primary care in RLS is indicative of insufficient investment in healthcare.[61] We strongly urge the continued and expanded use of PO, as its use in primary care and subsequent adequate management would save lives.[50 62] Further prospective research work with a stronger study design is needed to explore optimised strategies to improve hospital referral and reduce mortality.[22]

Author affiliations
[1]Inserm, Center for Epidemiology and Research in Population Health (CERPOP), University of Toulouse, Toulouse, France

[2]CLERSE - Centre Lillois d'Études et de Recherches Sociologiques et Économiques, University of Lille, Lille, France
[3]CHU de Bogodogo, Ouagadougou, Burkina Faso
[4]CHU Gabriel Touré, Bamako, Mali
[5]Institut de Nutrition et de Santé pour Enfants, Conakry, Guinea
[6]des populations et des affaires sociales, Ministère de la Santé, Niamey, Niger
[7]Tdh, Terre des Hommes Foundation, Dakar, Senegal
[8]The Alliance for International Medical Action, ALIMA, Dakar, Senegal
[9]Solthis, Solidarité Thérapeutique et Initiatives pour la Santé, Paris, France
[10]IRD, Inserm, Ceped, Université Paris Cité, Paris, France

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Collaborators Children, families, UNITAID and The AIRE Research Study Group: Country investigators: Ouagadougou, Burkina Faso: S Yugbaré Ouédraogo (PI), V M Sanon Zombré (CoPI), Conakry, Guinea: M Sama Cherif (CoPI), I S Diallo (CoPI), D F Kaba, (PI). Bamako, Mali: A A Diakité (PI), A Sidibé, (CoPI). Niamey, Niger: H Abarry Souleymane (CoPI), F Tidjani Issagana Dikouma (PI). Research coordinators and data centres: Inserm U1295, Toulouse 3 University, France: H Agbeci (international health economist), L Catala (research associate), D L Dahourou (research associate), S Desmonde (research associate), E Gres (PhD student), G B Hedible (international research project manager), V Leroy (research coordinator), L Peters Bokol (international clinical research monitor), J Tavarez (research project assistant), Z Zair (statistician, data scientist). CEPED, IRD, Paris, France: S Louart (process manager), V Ridde (process coordination). Inserm U1137, Paris, France: A Cousien (research associate). Inserm U1219, EMR271 IRD, Bordeaux University, France: R Becquet (research associate), V Briand (research associate), V Journot (research associate). PACCI, CHU Treichville, Abidjan, Côte d'Ivoire: S Lenaud (international data manager), C N'Chot (research associate), B Seri (supervisor IT), C Yao (data manager supervisor). Consortium NGOs partners: Alima-HQ (consortium lead), Dakar, Sénégal: G Anago (international monitoring evaluation accountability and learning officer), D Badiane (supply chain manager), M Kinda (director), D Neboua (medical officer), P S Dia (supply chain manager), S Shepherd (referent NGO), N di Mauro (operations support officer), G Noël (knowledge broker), K Nyoka (communication and advocacy officer), W Taokreo (finance manager), O B Coulidiati Lompo (finance manager), M Vignon (project Manager). Alima, Conakry, Guinea: P Aba (clinical supervisor), N Diallo (clinical supervisor), M Ngaradoum (medical team leader), S Léno (data collector), A T Sow (data collector), A Baldé (data collector), A Soumah (data collector), B Baldé (data collector), F Bah (data collector), K C Millimouno (data collector), M Haba (data collector), M Bah (data collector), M Soumah (data collector), M Guilavogui (data collector), M N Sylla (data collector), S Diallo (data collector), S F Dounfangadouno (data collector), T I Bah (data collector), S Sani (data collector), C Gnongoue (monitoring evaluation accountability and learning officer), S Gaye (monitoring evaluation accountability and learning officer), J P Y Guilavogui (clinical research assistant), A O Touré (country health economist), J S Kolié (country clinical research monitor), A S Savadogo (country project manager). Alima, Bamako, Mali: F Sangala (medical team leader), M Traore (clinical supervisor), T Konare (clinical supervisor), A Coulibaly (country health economist), A Keita (data collector), D Diarra (data collector), H Traoré (data collector), I Sangaré (data collector), I Koné (data collector), M Traoré (data collector), S Diarra (data collector), V Opoue (monitoring evaluation accountability and learning officer), F K Keita (medical coordinator), M Dougabka (clinical research assistant then monitoring evaluation accountability and learning officer), B Dembélé (data collector then clinical research assistant), M S Doumbia (country health economist), G D Kargougou (country clinical research monitor), S Keita (country project manager). Solthis-HQ, Paris: S Bouille (NGO referent), S Calmettes (NGO referent), F Lamontagne (NGO referent). Solthis, Niamey: K H Harouna (clinical supervisor), B Moutari (clinical supervisor), I Issaka (clinical supervisor), S O Assoumane (clinical supervisor), S Dioiri (medical team leader), M Sidi (data collector), K Sani Alio (country supply chain officer), S Amina (data collector), R Agbokou (clinical research assistant), M G Hamidou (clinical research assistant), S M Sani (country health economist), A Mahamane, Aboubacar Abdou (data collector), B Ousmane (data collector), I Kabirou (data collector), I Mahaman (data collector), I Mamoudou (data collector), M Baguido (data collector), R Abdoul (data collector), A Sahabi (data collector), F Seini (data collector), Z Hamani (data collector), L-Y B Meda (country clinical research monitor), Mactar Niome (country project manager), X Toviho (monitoring evaluation accountability and learning officer), I Sanouna (monitoring evaluation accountability and learning officer), P Kouam (programme officer). Terre des hommes-HQ, Lausanne: S Busière (NGO referent), F Triclin (NGO referent). Terre des hommes, BF: A Hema (country project manager), M Bayala (IeDA IT), L Tapsoba (monitoring evaluation accountability and learning officer), J B Yaro (clinical research assistant), S Sougue (clinical research assistant), R Bakyono (country health economist), A G Sawadogo (country clinical research monitor), A Soumah (data collector), Y A Lompo (data collector), B Malgoubri (data collector), F Douamba (data collector), G Sore (data collector), L Wangraoua (data collector), S Yamponi (data collector), S I Bayala (data collector), S Tiegna (data collector), S Kam (data collector), S Yoda (data collector), M Karantao (data collector), D F Barry (clinical supervisor), O Sanou (clinical supervisor), N Nacoulma (medical team leader), N Semde (clinical supervisor), I Ouattara (clinical supervisor), F Wango (clinical supervisor), Z Gneissien (clinical supervisor), H Congo (clinical supervisor). Terre des hommes, Mali: Y Diarra (clinical supervisor), B Ouattara (clinical supervisor), A Maiga (data collector), F Diabate (data collector), O Goita (data collector), S Gana (data collector), S Diallo (data collector), S Sylla (data collector), D Coulibaly (Tdh project manager), N Sakho (NGO referent). Country SHS team: Burkina Faso: K Kadio (consultant and research associate), J Yougbaré (data collector), D Zongo (data collector), S Tougouma (data collector), A Dicko (data collector), Z Nanema (data collector), I Balima (data collector), A Ouedraogo (data collector), A Ouattara (data collector), S E Coulibaly (data collector). Guinea: H Baldé (consultant and research associate), L Barry (data collector), E Duparc Haba (data collector). Mali: A Coulibaly (consultant and research associate), T Sidibe (data collector), Y Sangare (data collector), B Traore (data collector), Y Diarra (data collector). Niger: A E Dagobi (consultant and research associate), S Salifou (data collector), B Gana Moustapha Chétima (data collector), I H Abdou (data collector).

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Ethics approval This study involves human participants. The aggregated health data were extracted with the agreement and under the responsibility of each ministry of health involved in the AIRE project. Ethics approval and consent to participate 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. Consent was obtained from parents or tutor: patient representatives.

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Data availability statement Data may be obtained from a third party and are not publicly available. The datasets generated and analysed during the current study are not publicly available. Access to processed deidentified participant data will be made available to any third party after the publication of the main AIRE results stated in the Pan African Clinical Trial Registry Study statement (PACTR202206525204526, registered on 15 June 2022), on a motivated request (concept sheet) and after the written consent of the AIRE research coordinator

(Valeriane Leroy, valeriane.leroy@inserm.fr, Inserm U1295 Toulouse, France, orcid.org/0000-0003-3542-8616) obtained after the approval of the AIRE Publication Committee, if still active.

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ORCID iDs
Sarah Louart https://orcid.org/0000-0001-5330-7434
Franck Lamontagne https://orcid.org/0009-0009-6026-6445
Valery Ridde https://orcid.org/0000-0001-9299-8266
Valeriane Leroy https://orcid.org/0000-0003-3542-8616

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