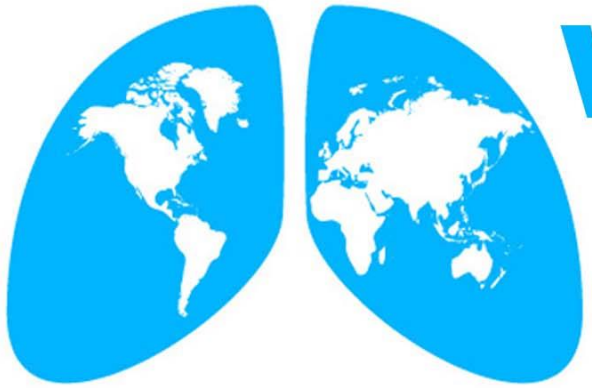
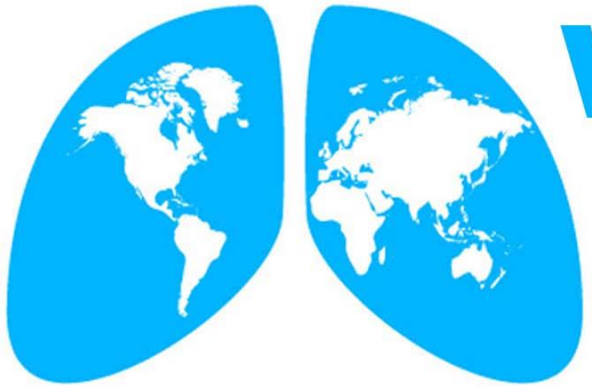


world pneumonia day

Fighting Pneumonia: An Agenda for Action

World Pneumonia Day 2022



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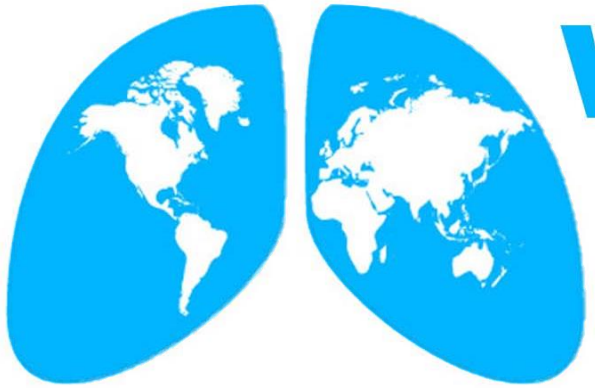
The Critical Role of Pulse Oximetry in Reducing Childhood Pneumonia Deaths

World Pneumonia Day 2022



world pneumonia day

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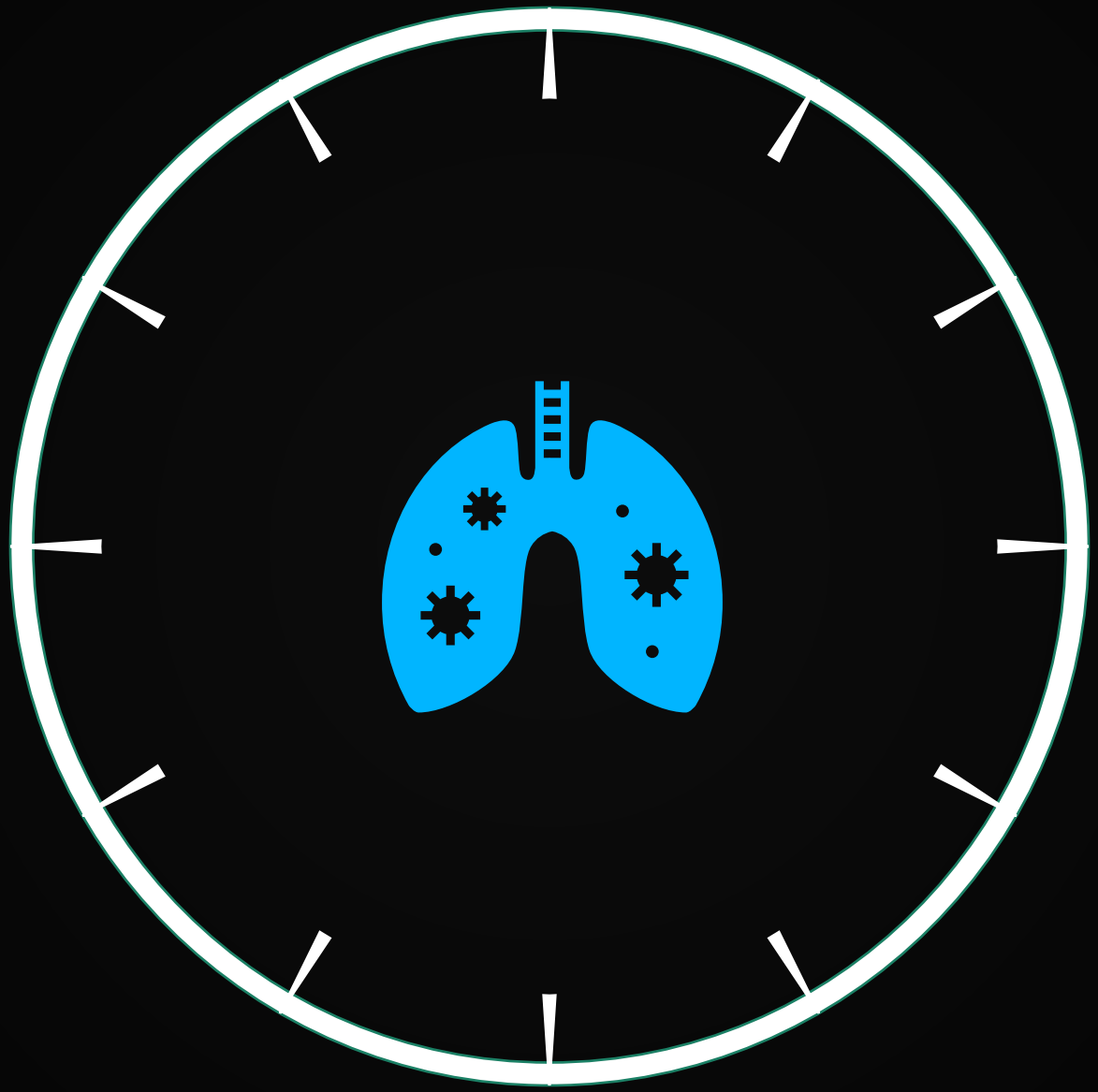

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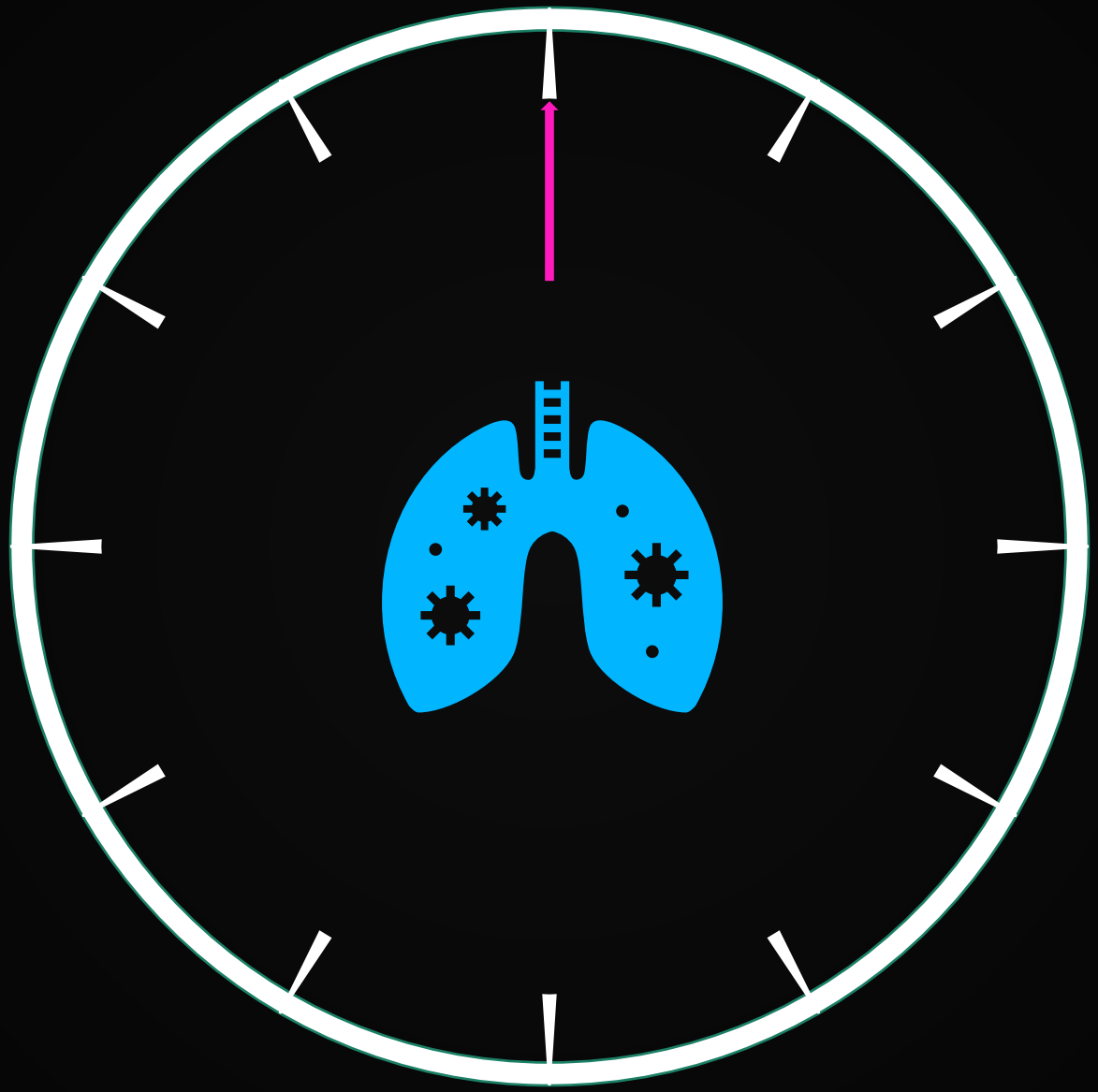

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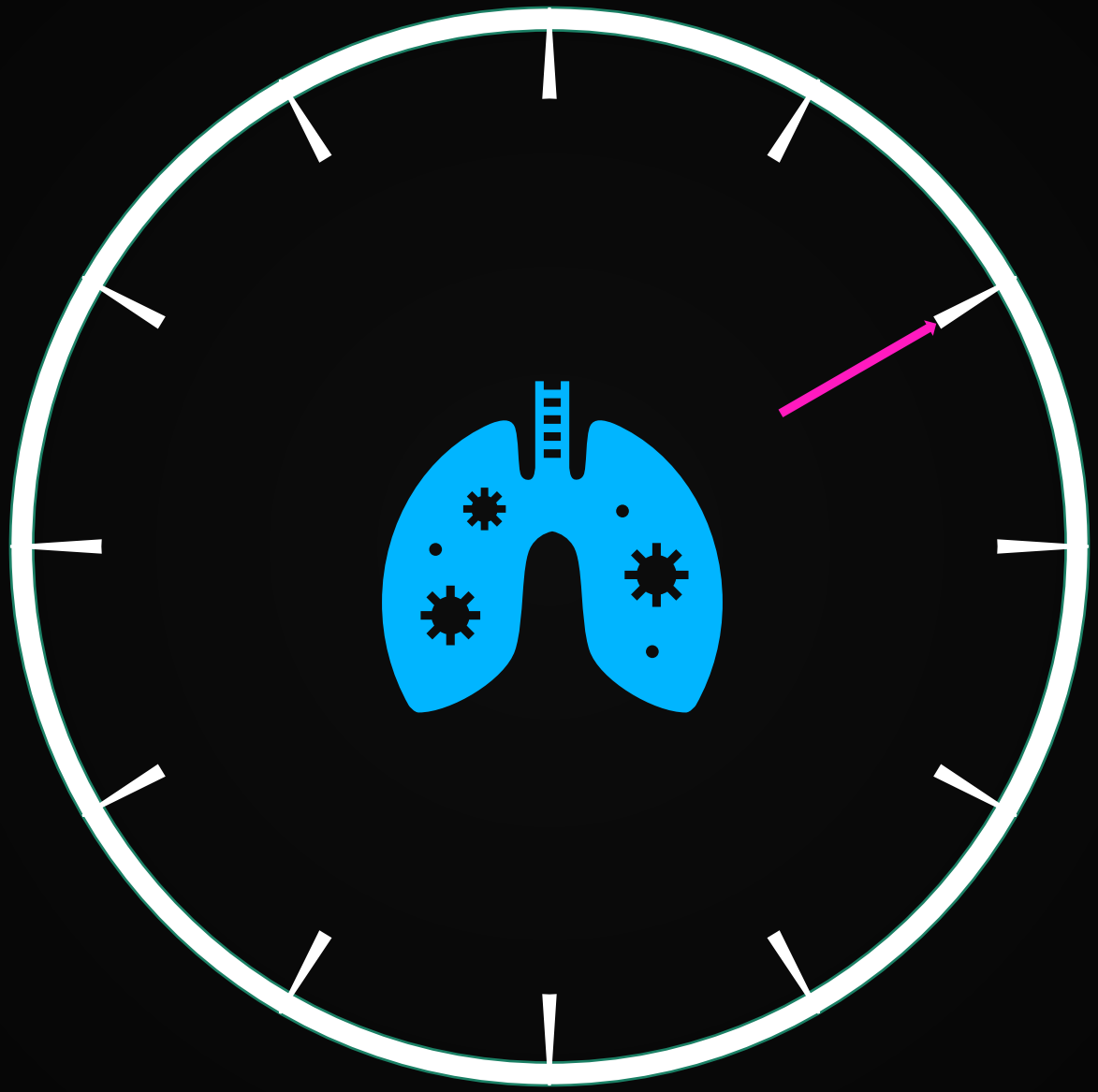

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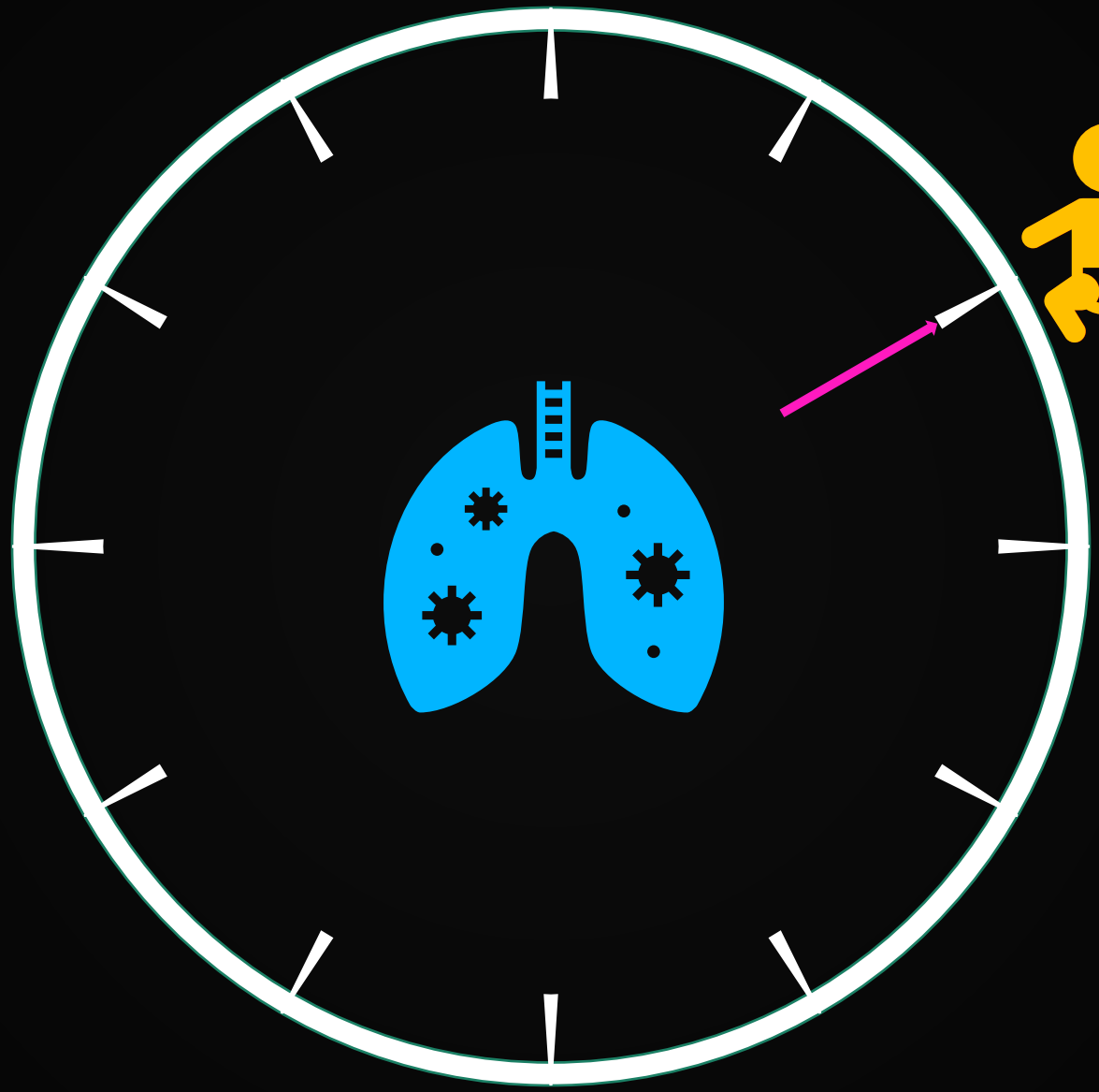
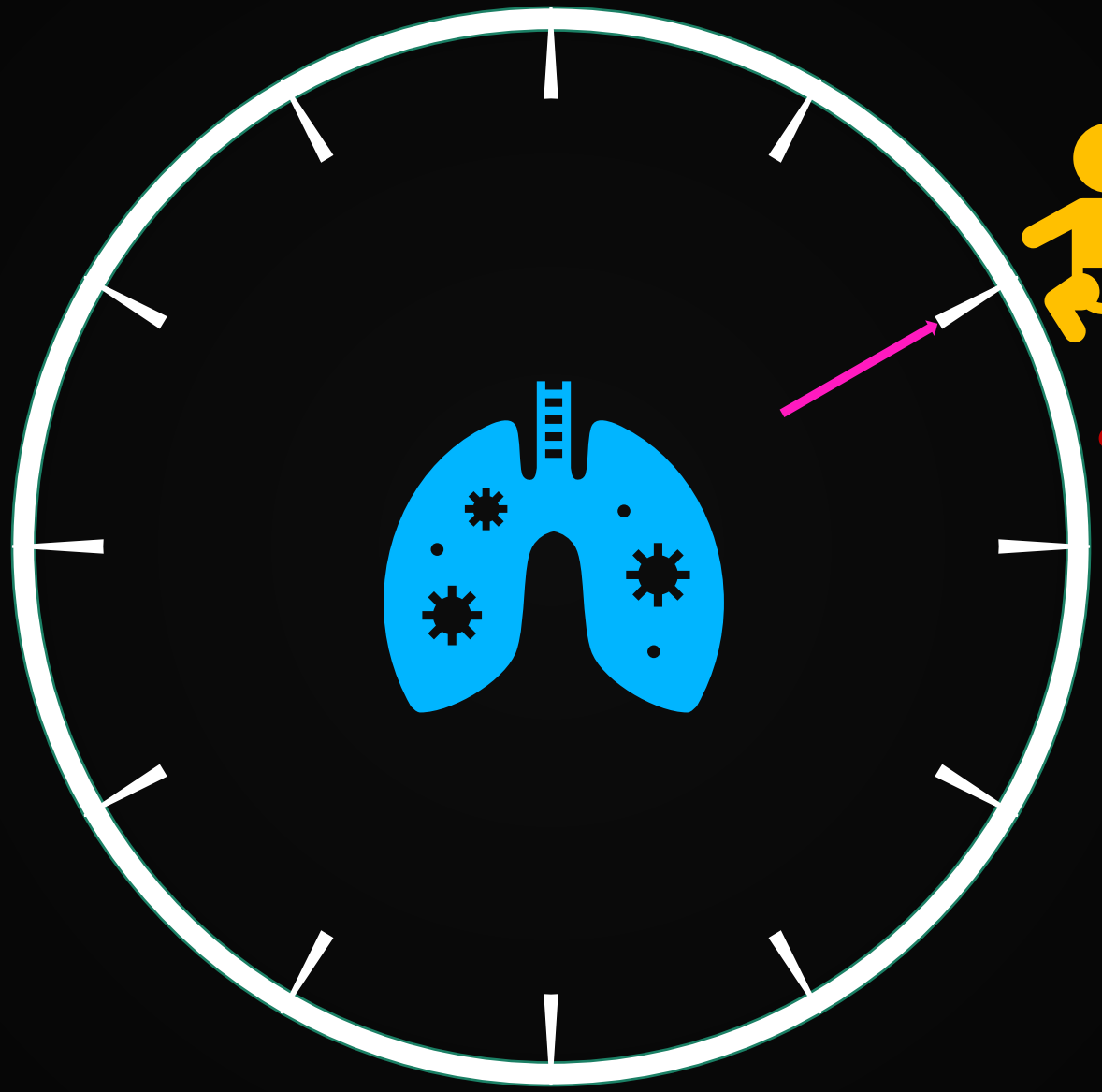


2600 cases

17 deaths

World Pneumonia Day 2022



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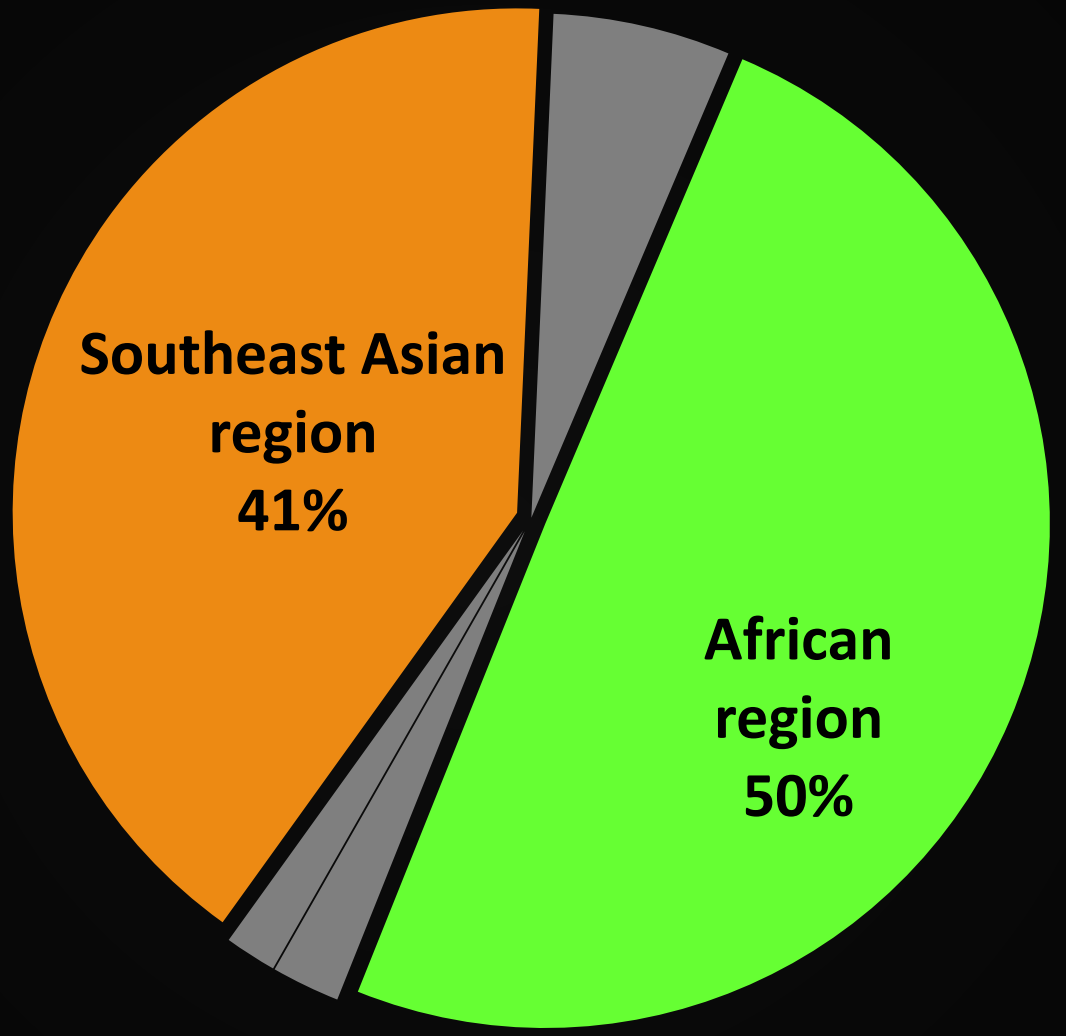

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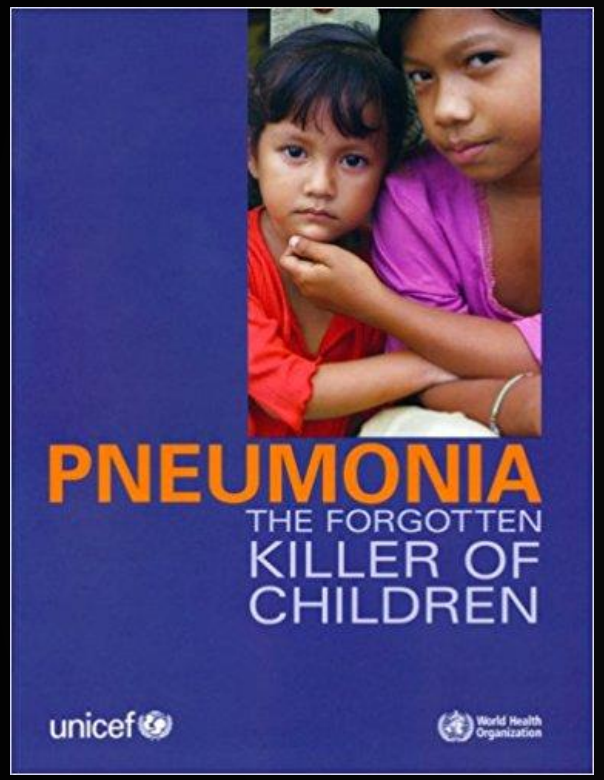

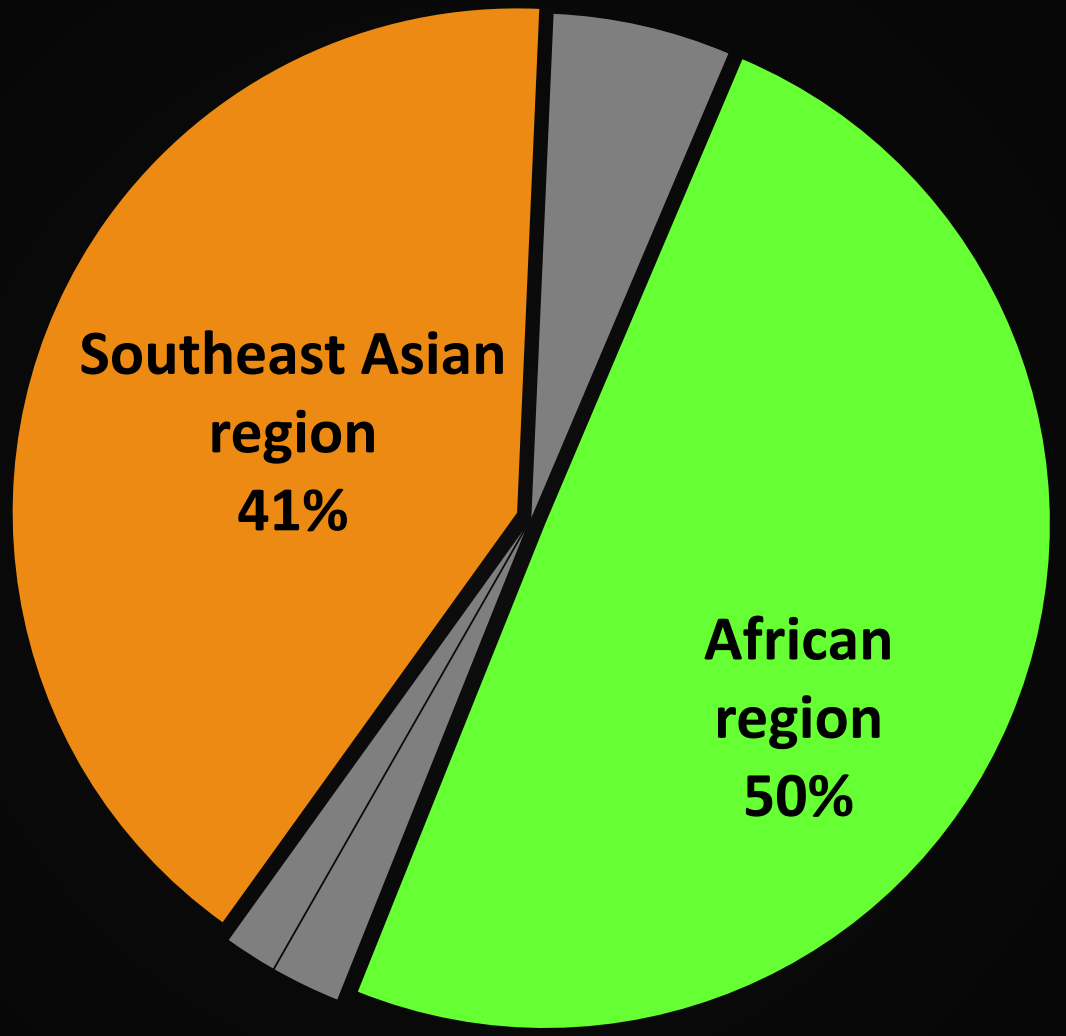

World Pneumonia Day 2022

Childhood Pneumonia

Is Hypoxaemia Common?
Does Hypoxaemia Kill?

World Pneumonia Day 2022

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Childhood Pneumonia

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Prevalence of hypoxaemia in children with pneumonia in low-income and middle-income countries: a systematic review and meta-analysis

Ahmed Ehsanur Rahman, Aniqa Tasnim Hossain, Harish Nair, Mohammod Jobayer Chisti, David Dockrell, Shams El Arifeen, Harry Campbell**

Summary

Background Pneumonia accounts for around 15% of all deaths of children younger than 5 years globally. Most happen in resource-constrained settings and are potentially preventable. Hypoxaemia is one of the strongest predictors of these deaths. We present an updated estimate of hypoxaemia prevalence among children with pneumonia in low-income and middle-income countries.

Methods We conducted a systematic review using the following key concepts "children under five years of age" AND "pneumonia" AND "hypoxaemia" AND "low- and middle-income countries" by searching in 11 bibliographic databases and citation indices. We included all articles published between Nov 1, 2008, and Oct 8, 2021, based on observational studies and control arms of randomised and non-randomised controlled trials. We excluded protocol papers, articles reporting hypoxaemia prevalence based on less than 100 pneumonia cases, and articles published before 2008 from the review. Quality appraisal was done with the Joanna Briggs Institute tools. We reported pooled prevalence of hypoxaemia (SpO_2 <90%) by classification of clinical severity and by clinical settings by use of the random-effects meta-analysis models. We combined our estimate of the pooled prevalence of pneumonia with a previously published estimate of the number of children admitted to hospital due to pneumonia annually to calculate the total annual number of children admitted to hospital with hypoxaemic pneumonia.

Findings We identified 2825 unique records from the databases, of which 57 studies met the eligibility criteria: 26 from Africa, 23 from Asia, five from South America, and four from multiple continents. The prevalence of hypoxaemia was 31% (95% CI 26–36; 101 775 children) among all children with WHO-classified pneumonia, 41% (33–49; 30 483 children) among those with very severe or severe pneumonia, and 8% (3–16; 2395 children) among those with non-severe pneumonia. The prevalence was much higher in studies conducted in emergency and inpatient settings than in studies conducted in outpatient settings. In 2019, we estimated that over 7 million children (95% CI 5–8 million) were admitted to hospital with hypoxaemic pneumonia. The studies included in this systematic review had high τ^2 (ie, 0·17), indicating a high level of heterogeneity between studies, and a high I^2 value (ie, 99·6%), indicating that the heterogeneity was not due to chance. This study is registered with PROSPERO, CRD42019126207.

Interpretation The high prevalence of hypoxaemia among children with severe pneumonia, particularly among children who have been admitted to hospital, emphasises the importance of overall oxygen security within the health systems of low-income and middle-income countries, particularly in the context of the COVID-19 pandemic. Even among children with non-severe pneumonia that is managed in outpatient and community settings, the high prevalence emphasises the importance of rapid identification of hypoxaemia at the first point of contact and referral for appropriate oxygen therapy.

Funding UK National Institute for Health Research (Global Health Research Unit on Respiratory Health [RESPIRE]; 16/136/109).

Lancet Glob Health 2022; 10: e348–59

See **Comment** page e301

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Correspondence to:
Dr Ahmed Ehsanur Rahman, The University of Edinburgh, Edinburgh EH8 9AG, UK
a.e.rahman@sms.ed.ac.uk

Introduction

Pneumonia accounts for approximately 15% of all deaths in children younger than 5 years, and most of these deaths occur in low-income and middle-income countries (LMICs).[1–3] Cognisant of the high burden of mortality, WHO declared pneumonia a "forgotten killer of children".[4] Without effectively preventing and treating pneumonia, countries with a high burden of pneumonia will not reach the ambitious UN Sustainable Development Goal target of reducing the mortality rate of children younger than 5 years to less than or equal to 25 per 1000 livebirths by 2030.[5]

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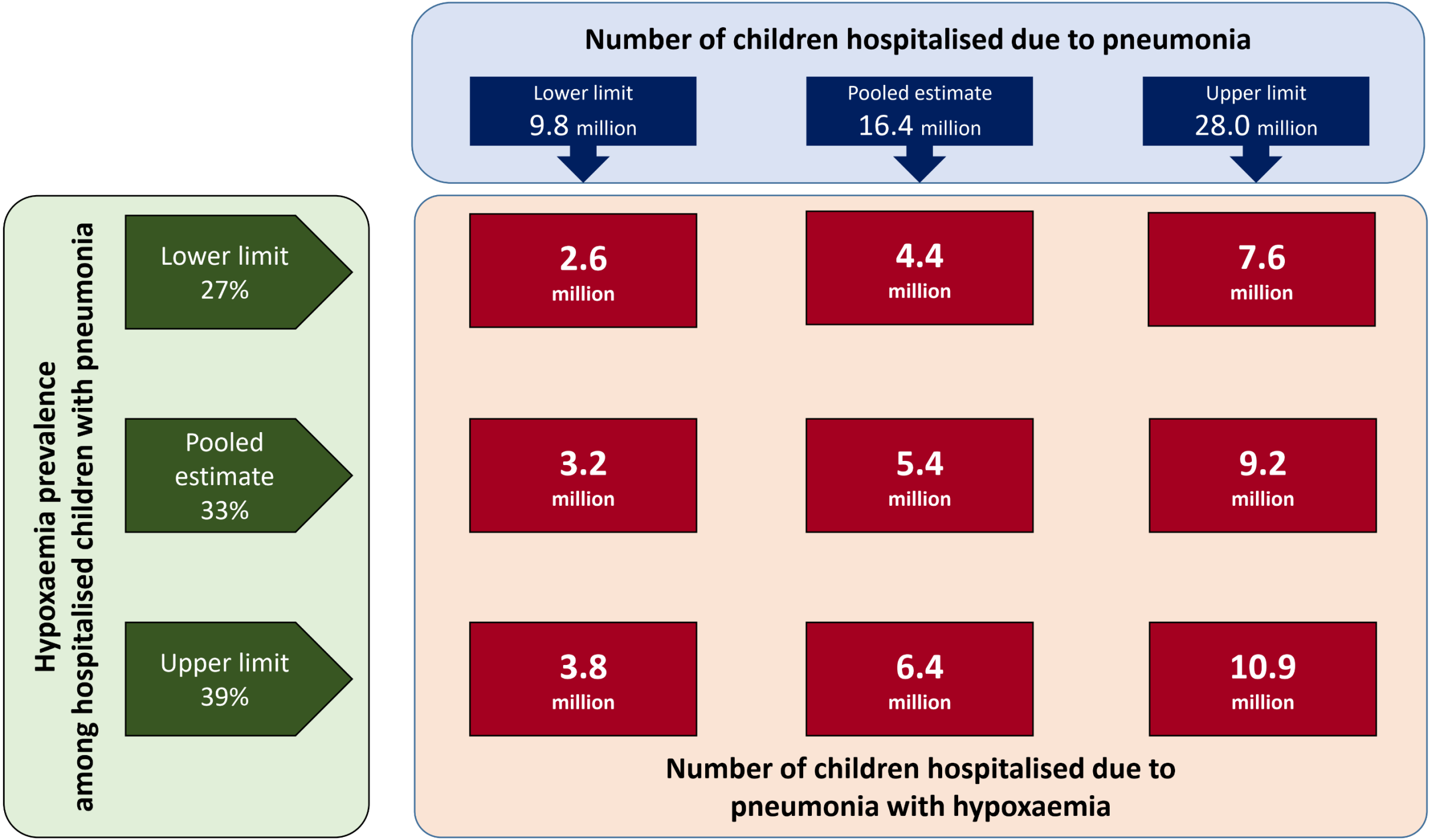
Hypoxaemia, defined as low oxygen saturation in arterial blood (ie, SpO_2 <90%), is common among

Severe Pneumonia	41%
Non-severe Pneumonia	8%
Unclassified Pneumonia	25%
Overall	31%


Number of children hospitalised due to pneumonia
Lower limit
9.8 million
Pooled estimate
16.4 million
Upper limit
28.0 million
Hypoxaemia prevalence among hospitalised children with pneumonia
Lower limit
27%
Pooled estimate
33%
Upper limit
39%
2.6
million
4.4
million
7.6
million
3.2
million
5.4
million
9.2
million
3.8
million
6.4
million
10.9
million
Number of children hospitalised due to pneumonia with hypoxaemia

PLOS ONE

RESEARCH ARTICLE

Hypoxaemia as a Mortality Risk Factor in Acute Lower Respiratory Infections in Children in Low and Middle-Income Countries: Systematic Review and Meta-Analysis

Marzia Lazzerini[1]*, Michela Sonego[1,2], Maria Chiara Pellegrin[2]

1 WHO Collaborating Centre for Maternal and Child Health, Institute for Maternal and Child Health IRCCS Burlo Garofolo, Via dell'Istria 65/1, 34137, Trieste, Italy, **2** University of Trieste, Piazzale Europa, 1 34127 Trieste, Italy

* marzia.lazzerini@burlo.trieste.it

OPEN ACCESS

Citation: Lazzerini M, Sonego M, Pellegrin MC (2015) Hypoxaemia as a Mortality Risk Factor in Acute Lower Respiratory Infections in Children in Low and Middle-Income Countries: Systematic Review and Meta-Analysis. PLoS ONE 10(9): e0136166. doi:10.1371/journal.pone.0136166

Editor: Zulfiqar A. Bhutta, The Hospital for Sick Children, CANADA

Received: February 27, 2015

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Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Funding: The authors have no support or funding to report.

Competing Interests: The authors have declared that no competing interests exist.

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Objective

To evaluate the association between hypoxaemia and mortality from acute lower respiratory infections (ALRI) in children in low- and middle-income countries (LMIC).

Design

Systematic review and meta-analysis.

Study Selection

Observational studies reporting on the association between hypoxaemia and death from ALRI in children below five years in LMIC.

Data Sources

Medline, Embase, Global Health Library, Lilacs, and Web of Science to February 2015.

Risk of Bias Assessment

Quality In Prognosis Studies tool with minor adaptations to assess the risk of bias; funnel plots and Egger's test to evaluate publication bias.

Results

Out of 11,627 papers retrieved, 18 studies from 13 countries on 20,224 children met the inclusion criteria. Twelve (66.6%) studies had either low or moderate risk of bias. Hypoxaemia defined as oxygen saturation rate (SpO2) <90% associated with significantly increased odds of death from ALRI (OR 5.47, 95% CI 3.93 to 7.63) in 12 studies on 13,936 children.

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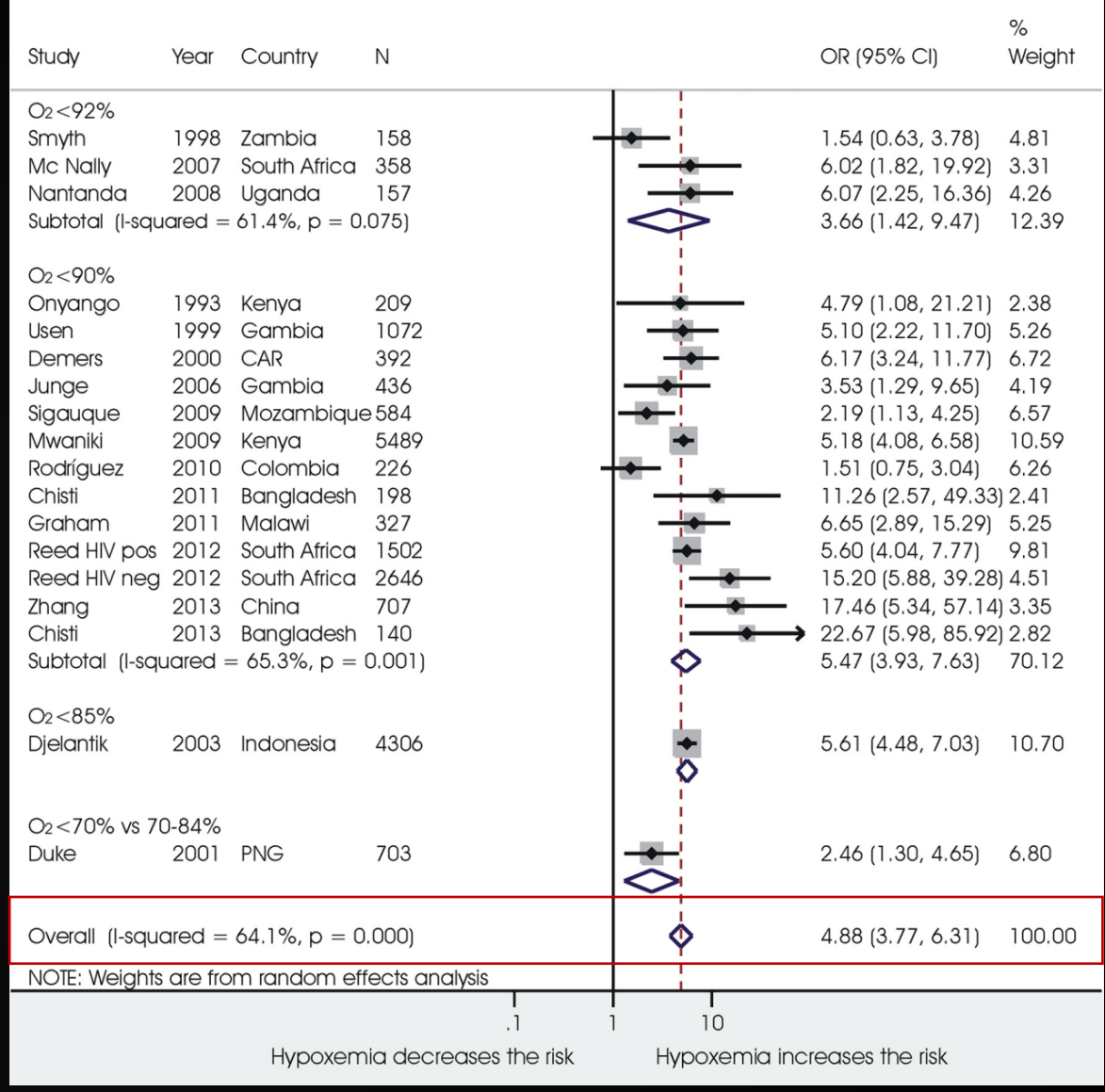

Mortality Risk in odds ration

5 times

Electronic supplementary material:
The online version of this article contains supplementary material.

journal of global health

Cite as: Rahman AE, Hossain AT, Chisti MJ, Dockrell DH, Nair H, Arifeen SE, Campbell H. Hypoxaemia prevalence and its adverse clinical outcomes among children hospitalised with WHO-defined severe pneumonia in Bangladesh. J Glob Health 2021;11:04053.

Hypoxaemia prevalence and its adverse clinical outcomes among children hospitalised with WHO-defined severe pneumonia in Bangladesh

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[1]The Usher Institute, Edinburgh Medical School: Molecular, Genetic and Population Health Sciences, The University of Edinburgh, Edinburgh, UK
[2]Maternal and Child Health Division, International Centre for Diarrhoeal Disease Research (icddr,b), Dhaka, Bangladesh
[3]Nutrition and Clinical Services Division, International Centre for Diarrhoeal Disease Research (icddr,b), Dhaka, Bangladesh

Background With an estimated 1 million cases per year, pneumonia accounts for 15% of all under-five deaths globally, and hypoxaemia is one of the strongest predictors of mortality. Most of these deaths are preventable and occur in low- and middle-income countries. Bangladesh is among the six high burden countries with an estimated 4 million pneumonia episodes annually. There is a gap in updated evidence on the prevalence of hypoxaemia among children with severe pneumonia in high burden countries, including Bangladesh.

Methods We conducted a secondary analysis of data obtained from icddr,b-Dhaka Hospital, a secondary level referral hospital located in Dhaka, Bangladesh. We included 2646 children aged 2-59 months admitted with WHO-defined severe pneumonia during 2014-17. The primary outcome of interest was hypoxaemia, defined as SpO_2<90% on admission. The secondary outcome of interest was adverse clinical outcomes defined as deaths during hospital stay or referral to higher-level facilities due to clinical deterioration.

Results On admission, the prevalence of hypoxaemia among children hospitalised with severe pneumonia was 40%. The odds of hypoxaemia were higher among females (adjusted Odds ratio AOR = 1.44; 95% confidence interval CI = 1.22-1.71) and those with a history of cough or difficulty in breathing for 0-48 hours before admission (AOR = 1.61; 95% CI = 1.28-2.02). Among all children with severe pneumonia, 6% died during the hospital stay, and 9% were referred to higher-level facilities due to clinical deterioration. Hypoxaemia was the strongest predictor of mortality (AOR = 11.08; 95% CI = 7.28-16.87) and referral (AOR = 5.94; 95% CI = 4.31-17) among other factors such as age, sex, history of fever and cough or difficulty in breathing, and severe acute malnutrition. Among those who survived, the median duration of hospital stay was 7 (IQR = 4-11) days in the hypoxaemic group and 6 (IQR = 4-9) days in the non-hypoxaemic group, and the difference was significant at P<0.001.

Conclusions The high burden of hypoxaemia and its clinical outcomes call for urgent attention to promote oxygen security in low resource settings like Bangladesh. The availability of pulse oximetry for rapid identification and an effective oxygen delivery system for immediate correction should be ensured for averting many preventable deaths.

Data repository name: icddr,b

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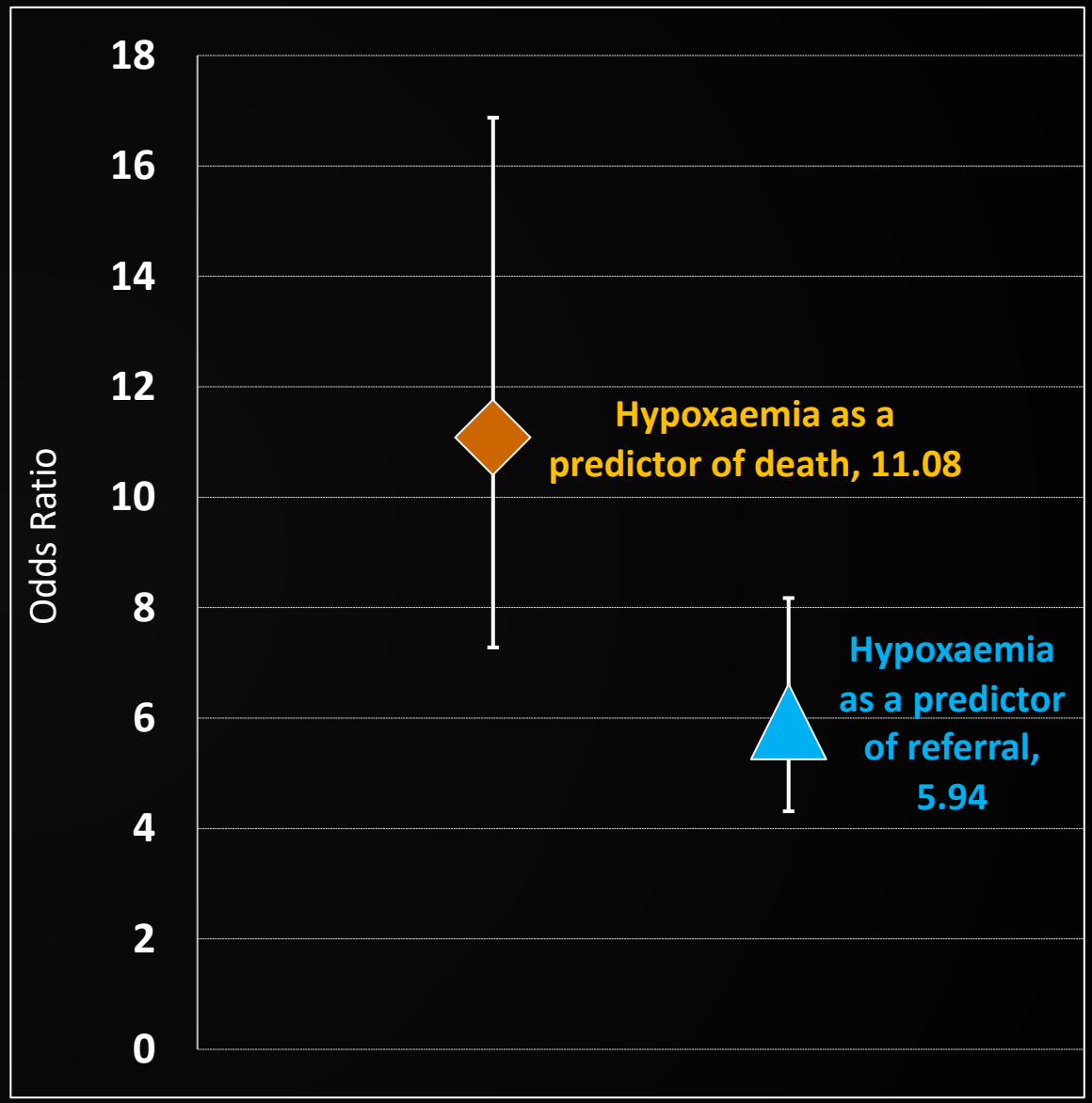

Childhood Pneumonia

Hypoxaemia is Common
Hypoxaemia Kills

World Pneumonia Day 2022

Childhood Pneumonia

Hypoxaemia is Common
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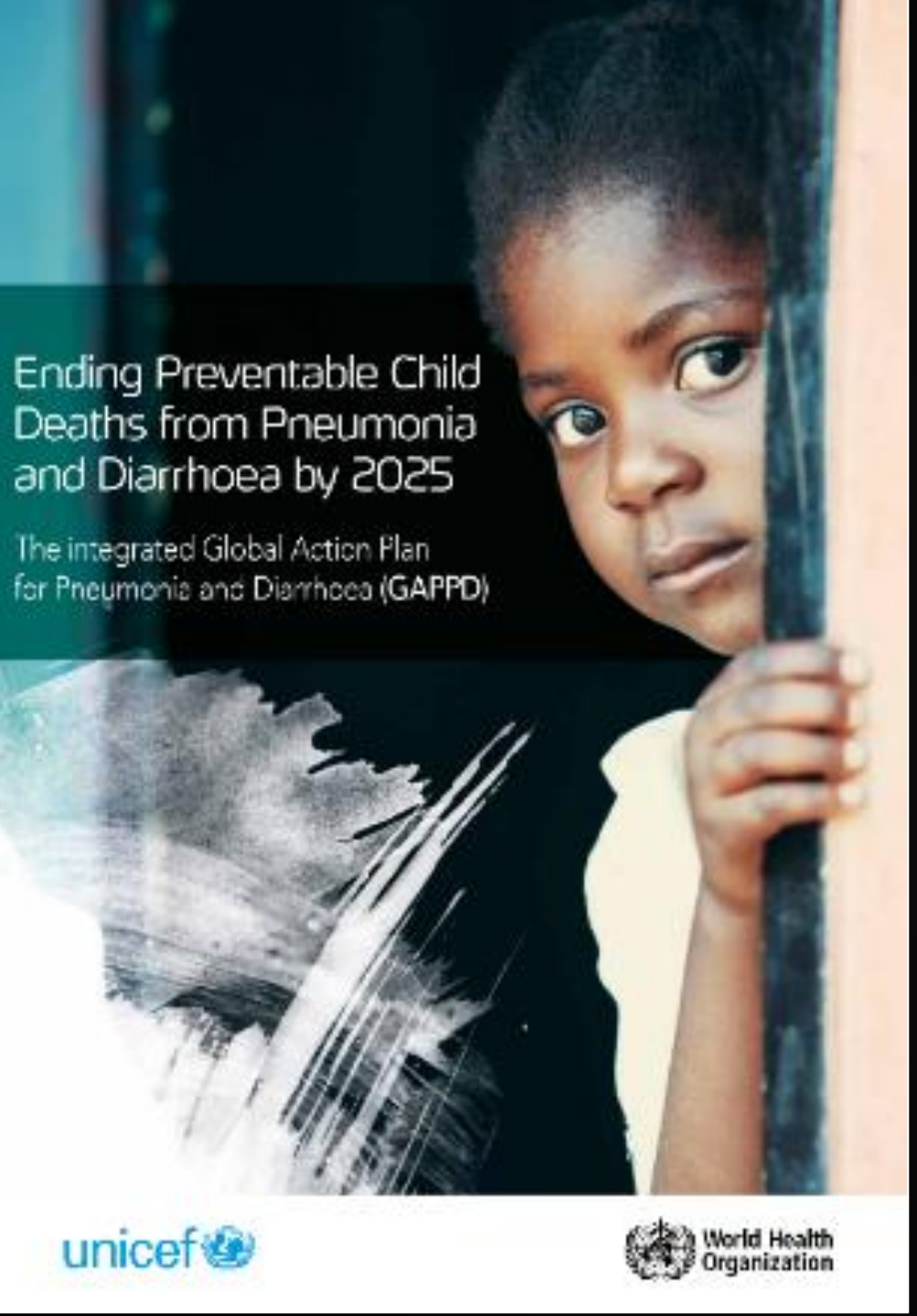
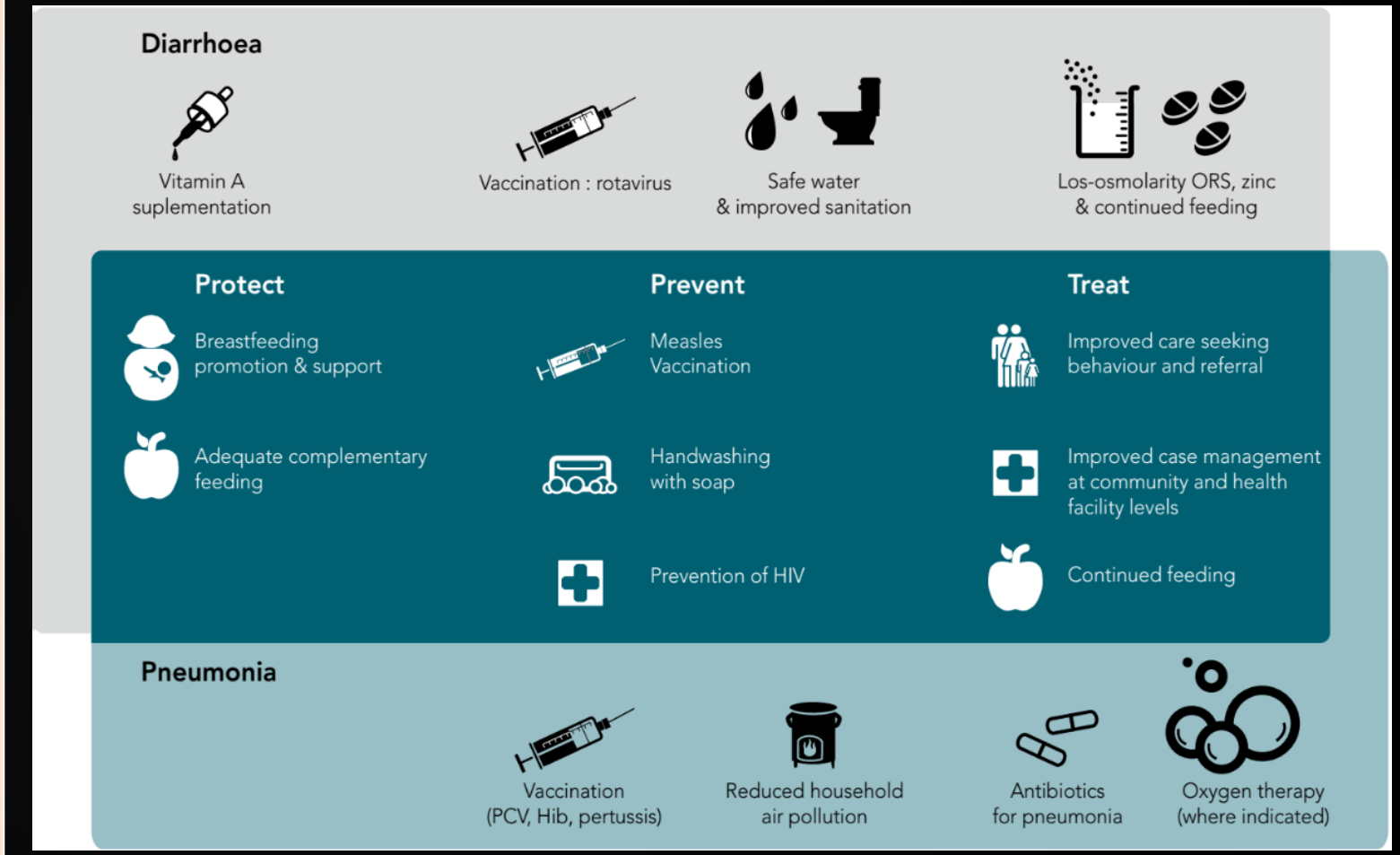
What can we do?





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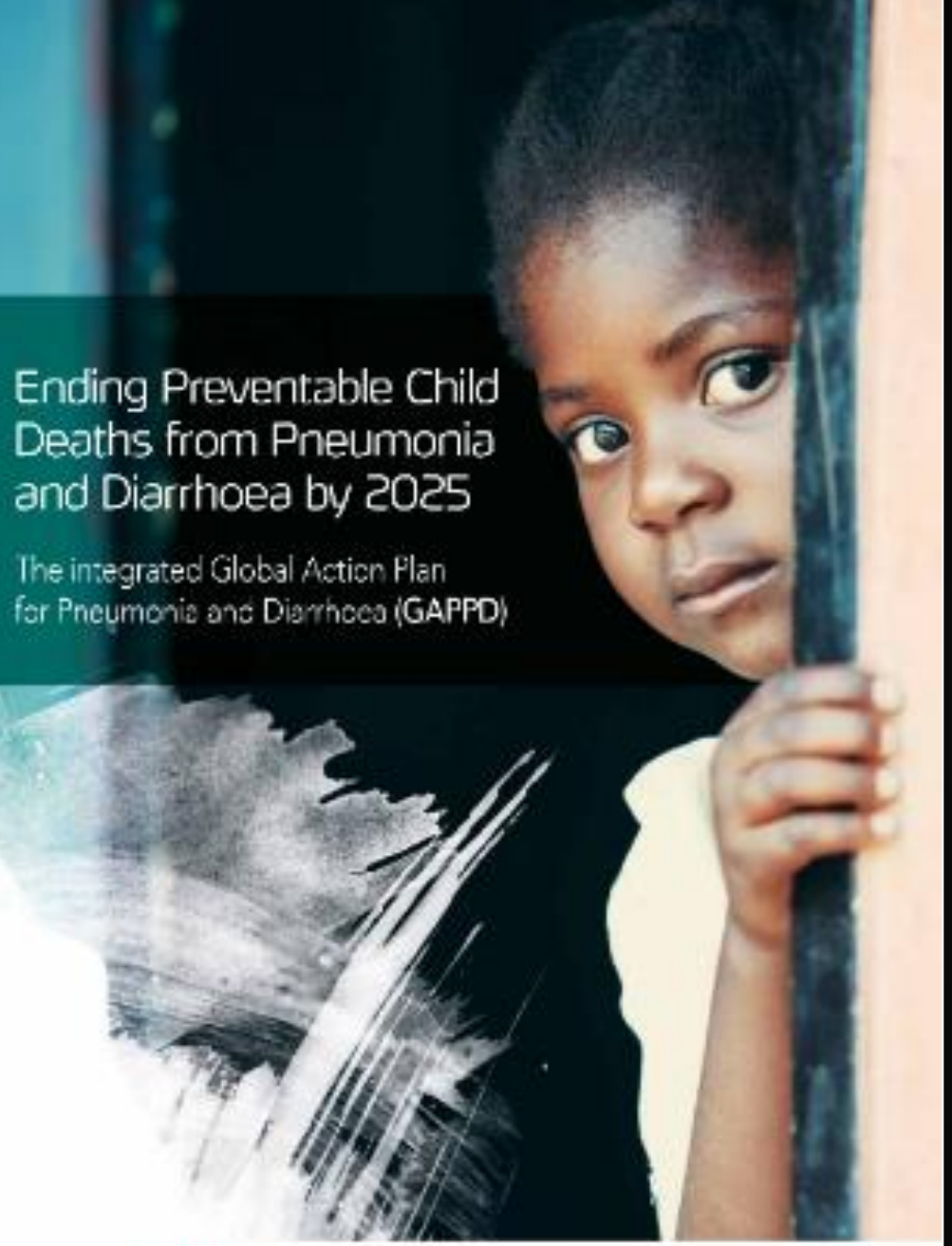

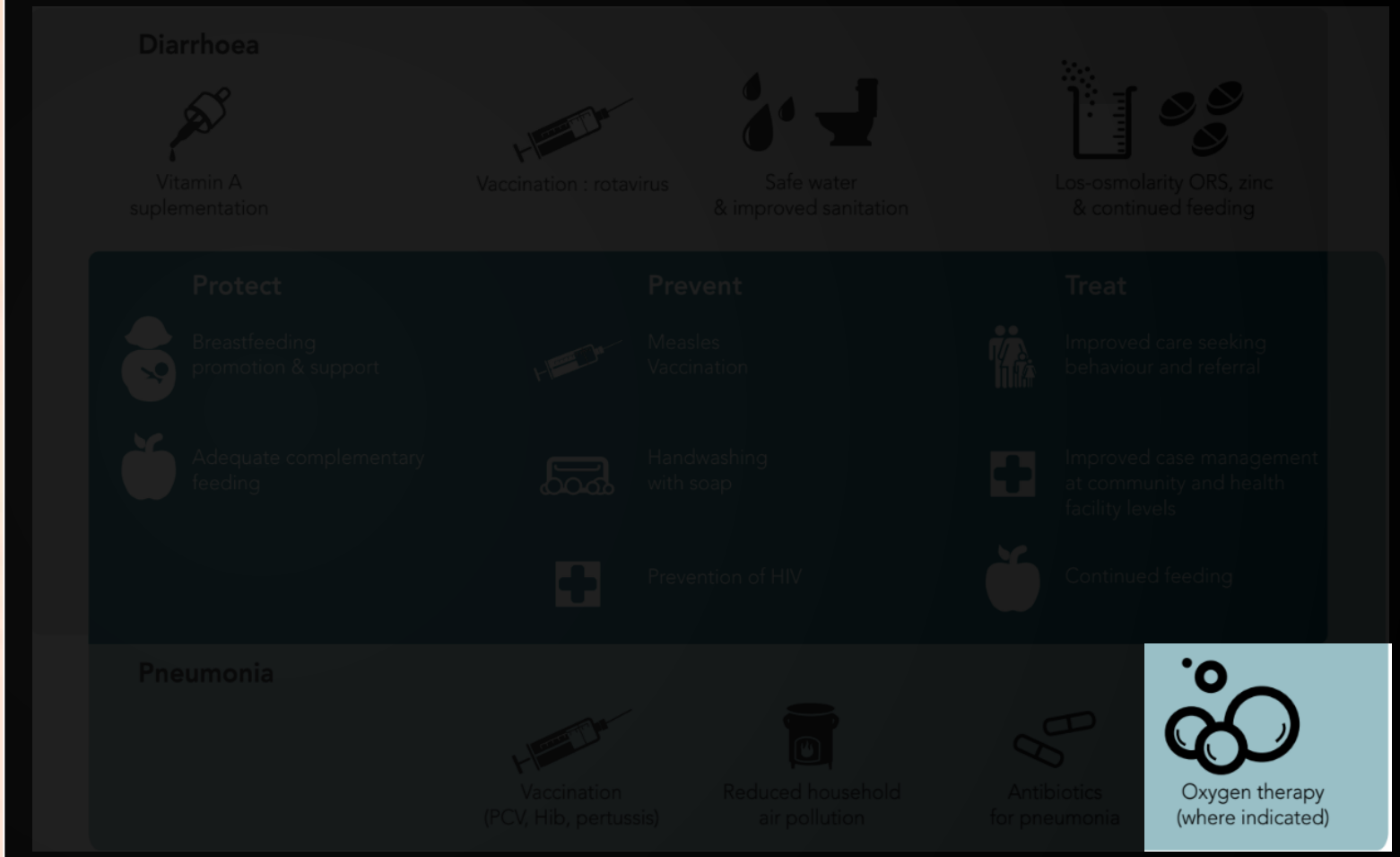

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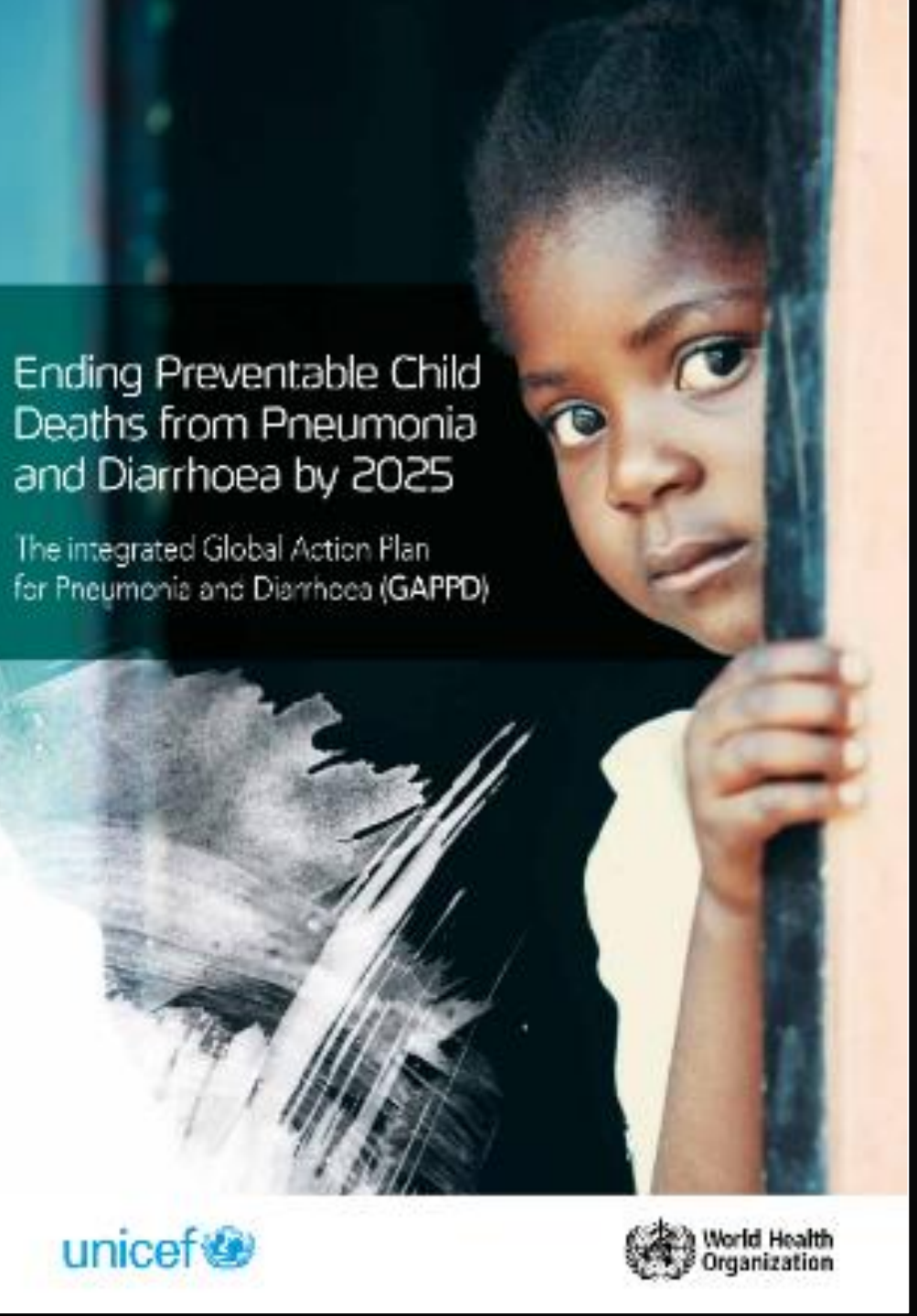

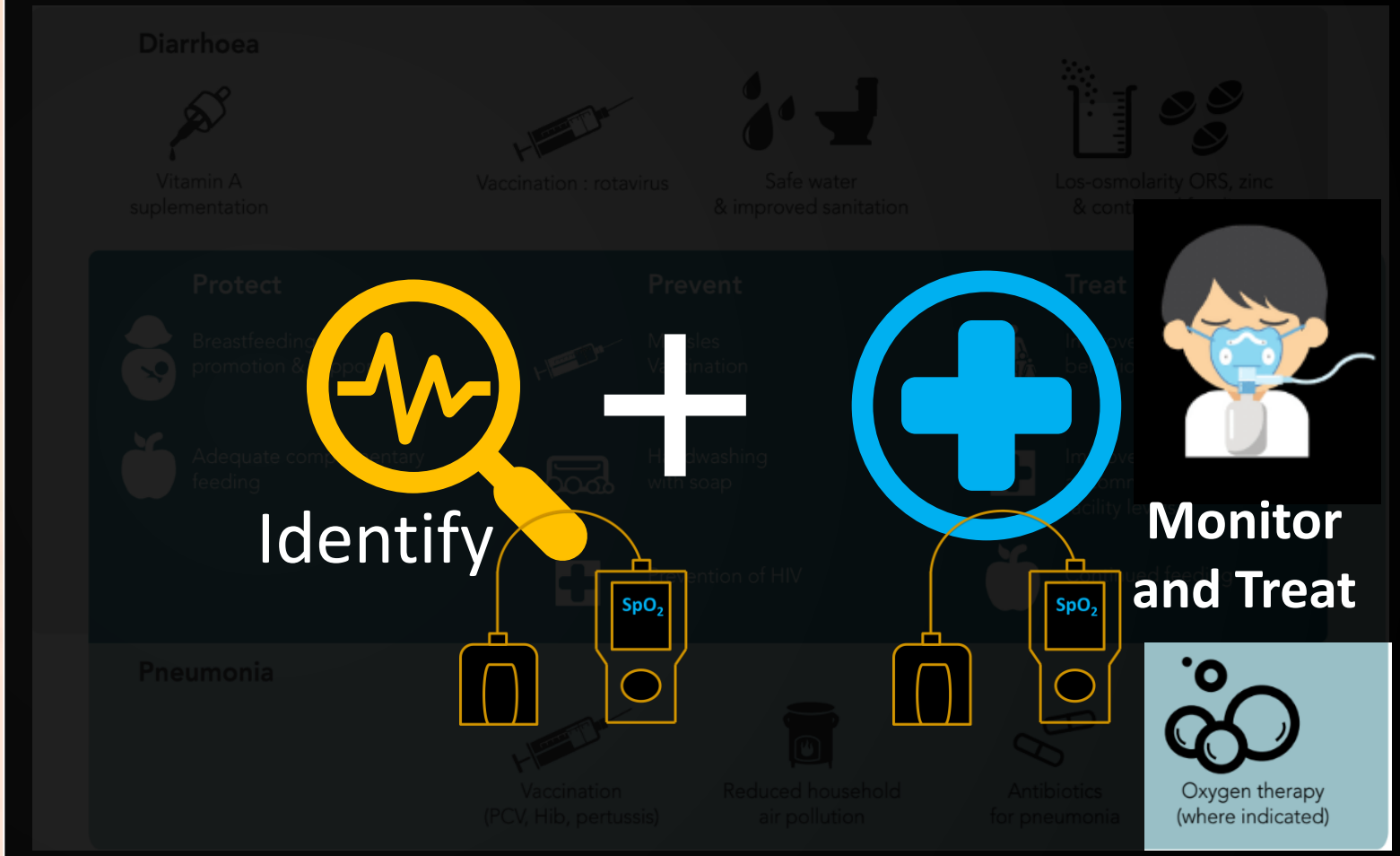

World Pneumonia Day 2022

Outpatient facility

Integrated Management of Childhood Illness

IMCI

Chart Booklet

World Health Organization

March 2014

THEN ASK ABOUT MAIN SYMPTOMS:
Does the child have cough or difficult breathing?

If yes, ask:	*Look, listen, feel*:*
• For how long?	• Count the breaths in one minute. • Look for chest indrawing. • Look and listen for stridor. • Look and listen for wheezing. CHILD MUST BE CALM

If wheezing with either fast breathing or chest indrawing:
Give a trial of rapid acting inhaled bronchodilator for up to three times 15-20 minutes apart. Count the breaths and look for chest indrawing again, and then classify.

If the child is:	*Fast breathing is:*
2 months up to 12 months	**50** breaths per minute or more
12 Months up to 5 years	**40** breaths per minute or more

Classify COUGH or DIFFICULT BREATHING

• Any general danger sign or • Stridor in calm child.	***Pink:*** **SEVERE PNEUMONIA OR VERY SEVERE DISEASE**	▪ **Give first dose of an appropriate antibiotic** ▪ **Refer URGENTLY to hospital****
• Chest indrawing or • Fast breathing.	***Yellow:*** **PNEUMONIA**	▪ **Give oral Amoxicillin for 5 days***** ▪ If wheezing (or disappeared after rapidly acting bronchodilator) give an inhaled bronchodilator for 5 days**** ▪ If chest indrawing in HIV exposed/infected child, give first dose of amoxicillin and refer. ▪ Soothe the throat and relieve the cough with a safe remedy ▪ If coughing for more than 14 days or recurrent wheeze, refer for possible TB or asthma assessment ▪ Advise mother when to return immediately ▪ Follow-up in 3 days
• No signs of pneumonia or very severe disease.	***Green:*** **COUGH OR COLD**	▪ If wheezing (or disappeared after rapidly acting bronchodilator) give an inhaled bronchodilator for 5 days**** ▪ Soothe the throat and relieve the cough with a safe remedy ▪ If coughing for more than 14 days or recurrent wheezing, refer for possible TB or asthma assessment ▪ Advise mother when to return immediately ▪ Follow-up in 5 days if not improving

**If pulse oximeter is available, determine oxygen saturation and refer if < 90%.*
*** If referral is not possible, manage the child as described in the pneumonia section of the national referral guidelines or as in WHO Pocket Book for hospital care for children.*
****Oral Amoxicillin for 3 days could be used in patients with fast breathing but no chest indrawing in low HIV settings.*
***** In settings where inhaled bronchodilator is not available, oral salbutamol may be tried but not recommended for treatement of severe acute wheeze.*

***If pulse oximetry available, determine SpO_2 & refer if SpO_2 <90%**

Childhood Pneumonia

We can use pulse oximetry for pneumonia assessment

Childhood Pneumonia

We can use pulse oximetry for pneumonia assessment

Is it feasible?

Introducing pulse oximetry for outpatient management of childhood pneumonia: An implementation research adopting a district implementation model in selected rural facilities in Bangladesh

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Summary

Background Pulse oximetry has potential for identifying hypoxaemic pneumonia and substantially reducing under-five deaths in low- and middle-income countries (LMICs) setting. However, there are few examples of introducing pulse oximetry in resource-constrained paediatric outpatient settings, such as Integrated Management of Childhood Illness (IMCI) services.

Methods The National IMCI-programme of Bangladesh designed and developed a district implementation model for introducing pulse oximetry in routine IMCI services through stakeholder engagement and demonstrated the model in Kushtia district adopting a health system strengthening approach. Between December 2020 and June 2021, two rounds of assessment were conducted based on WHO's implementation research framework and outcome variables, involving 22 IMCI service-providers and 1680 children presenting with cough/difficulty-in-breathing in 12 health facilities. The data collection procedures included structured-observations, re-assessments, interviews, and data-extraction by trained study personnel.

Findings We observed that IMCI service-providers conducted pulse oximetry assessments on all eligible children in routine outpatient settings, of which 99% of assessments were successful; 85% (95% CI 83,87) in one attempt, and 69% (95% CI 67,71) within one minute. The adherence to standard operating procedure related to pulse oximetry was 92% (95% CI 91,93), and agreement regarding identifying hypoxaemia was 97% (95% CI 96,98). The median performance-time was 36 seconds (IQR 20,75), which was longer among younger children (2-11 months: 44s, IQR 22,78; 12-59 months: 30s, IQR 18,53, $p < 0.01$) and among those classified as pneumonia/severe-pneumonia than as no-pneumonia (41s, IQR 22,70; 32s, IQR 20,62, $p < 0.01$). We observed improvements in almost all indicators in round-2. IMCI service-providers and caregivers showed positive attitudes towards using this novel technology for assessing their children.

Interpretation This implementation research study suggested the adoption, feasibility, fidelity, appropriateness, acceptability, and sustainability of pulse oximetry introduction in routine IMCI services in resource-poor settings. The learning may inform the evidence-based scale-up of pulse oximetry linked with an oxygen delivery system in Bangladesh and other LMICs.

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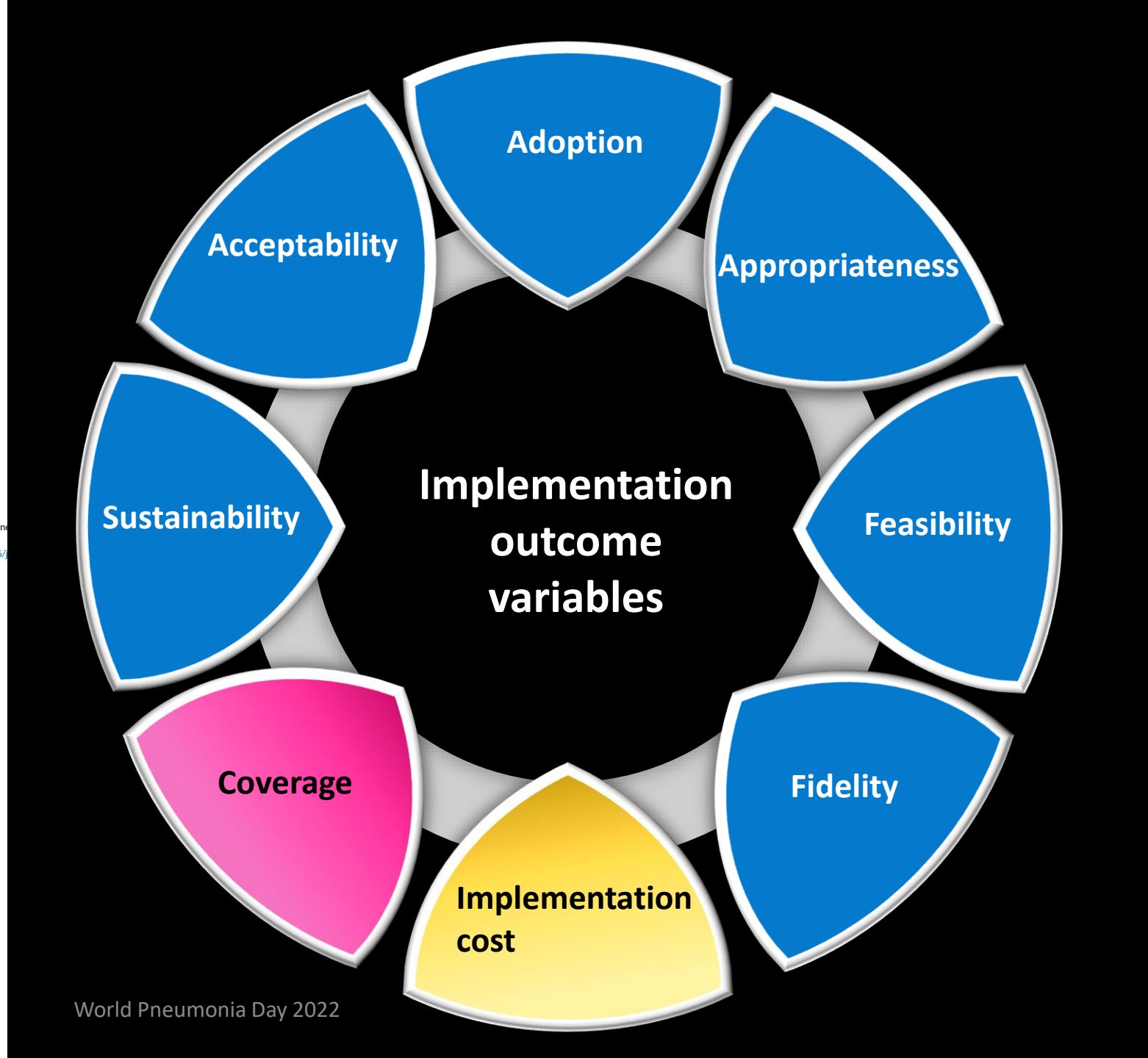

World Pneumonia Day 2022


%
0
20
40
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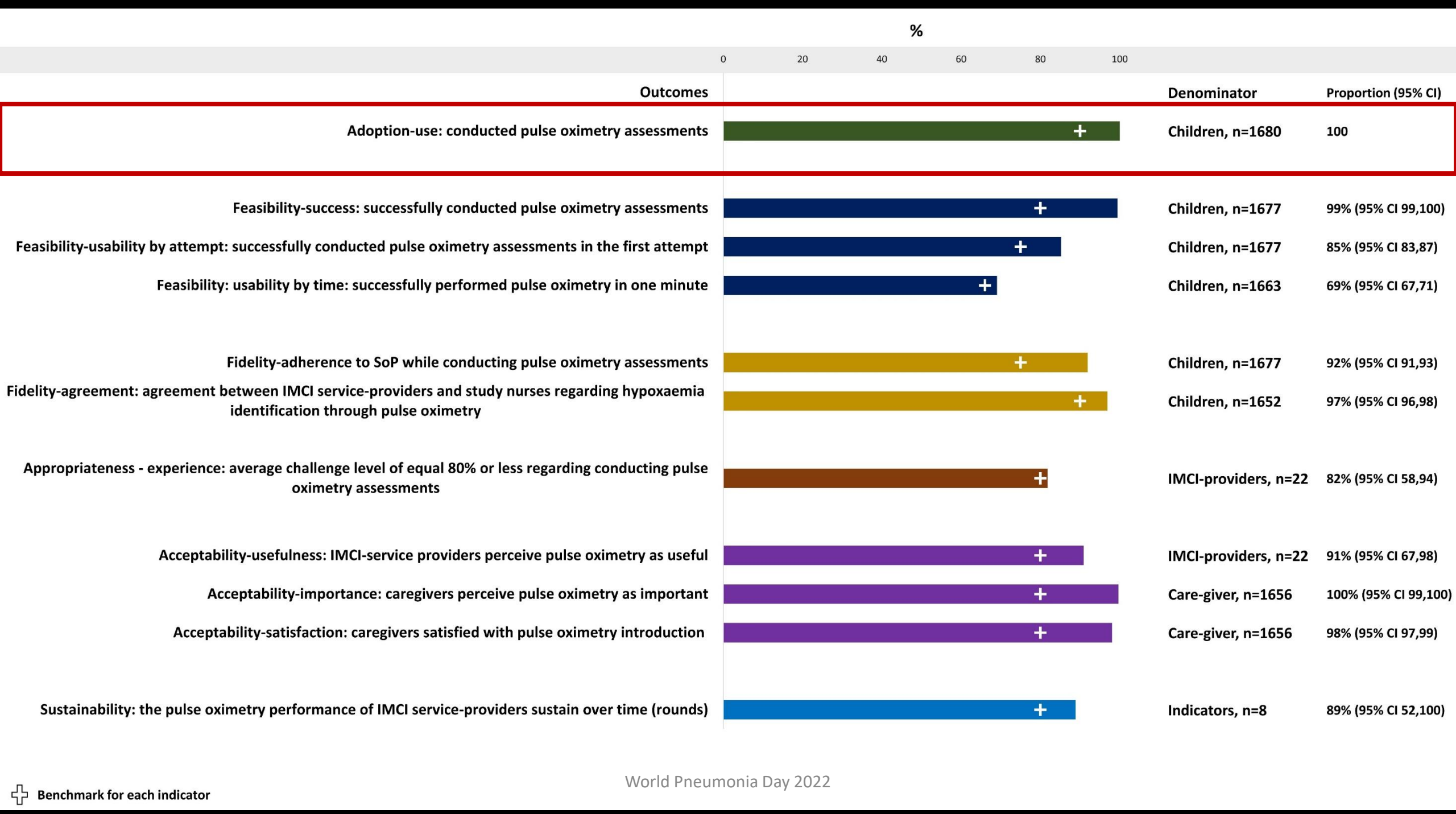
Outcomes
Denominator
Proportion (95% CI)
Adoption-use: conducted pulse oximetry assessments
Children, n=1680
100
Feasibility-success: successfully conducted pulse oximetry assessments
Children, n=1677
99% (95% CI 99,100)
Feasibility-usability by attempt: successfully conducted pulse oximetry assessments in the first attempt
Children, n=1677
85% (95% CI 83,87)
Feasibility: usability by time: successfully performed pulse oximetry in one minute
Children, n=1663
69% (95% CI 67,71)
Fidelity-adherence to SoP while conducting pulse oximetry assessments
Children, n=1677
92% (95% CI 91,93)
Fidelity-agreement: agreement between IMCI service-providers and study nurses regarding hypoxaemia identification through pulse oximetry
Children, n=1652
97% (95% CI 96,98)
Appropriateness - experience: average challenge level of equal 80% or less regarding conducting pulse oximetry assessments
IMCI-providers, n=22
82% (95% CI 58,94)
Acceptability-usefulness: IMCI-service providers perceive pulse oximetry as useful
IMCI-providers, n=22
91% (95% CI 67,98)
Acceptability-importance: caregivers perceive pulse oximetry as important
Care-giver, n=1656
100% (95% CI 99,100)
Acceptability-satisfaction: caregivers satisfied with pulse oximetry introduction
Care-giver, n=1656
98% (95% CI 97,99)
Sustainability: the pulse oximetry performance of IMCI service-providers sustain over time (rounds)
Indicators, n=8
89% (95% CI 52,100)
Benchmark for each indicator
World Pneumonia Day 2022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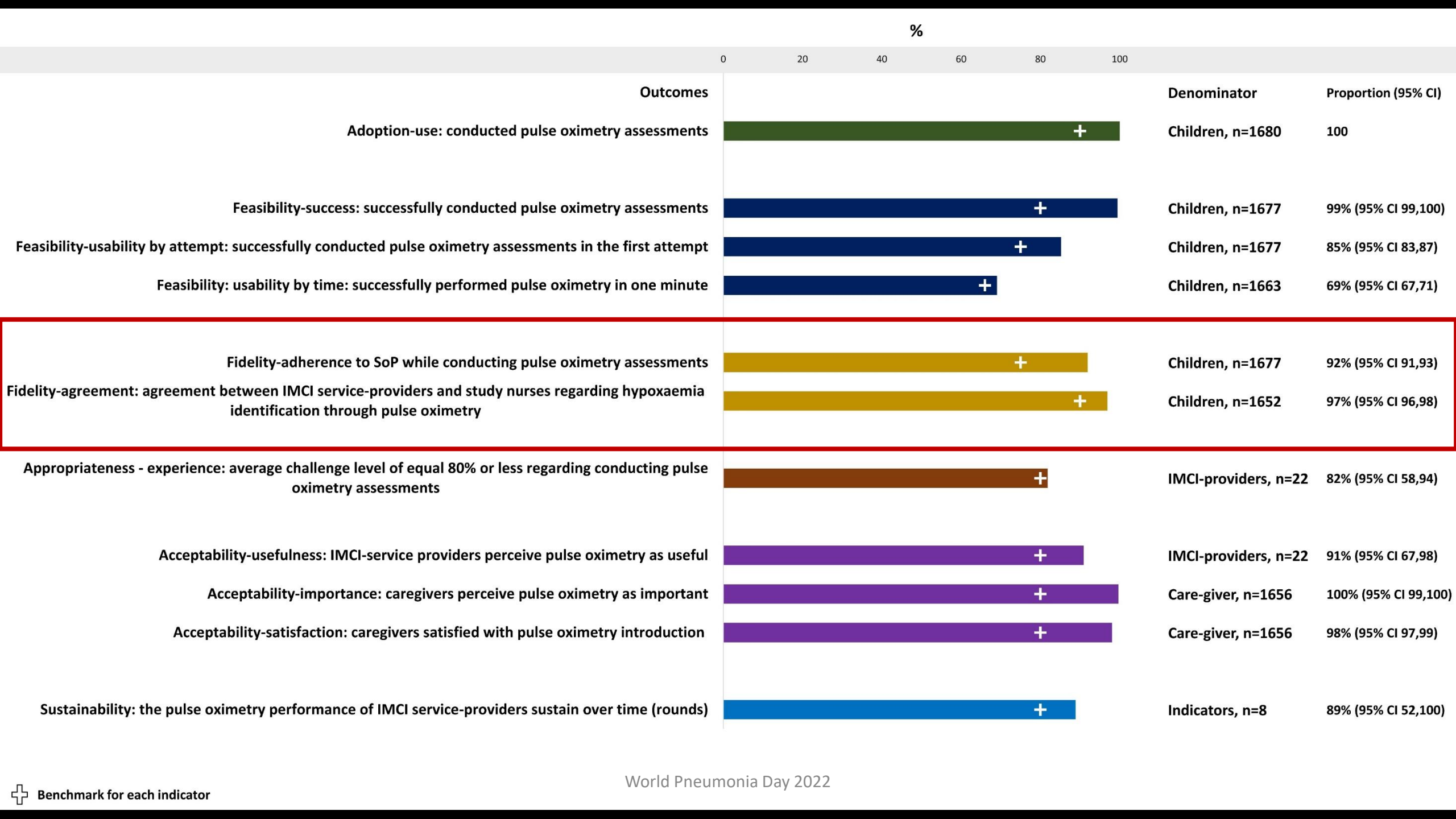
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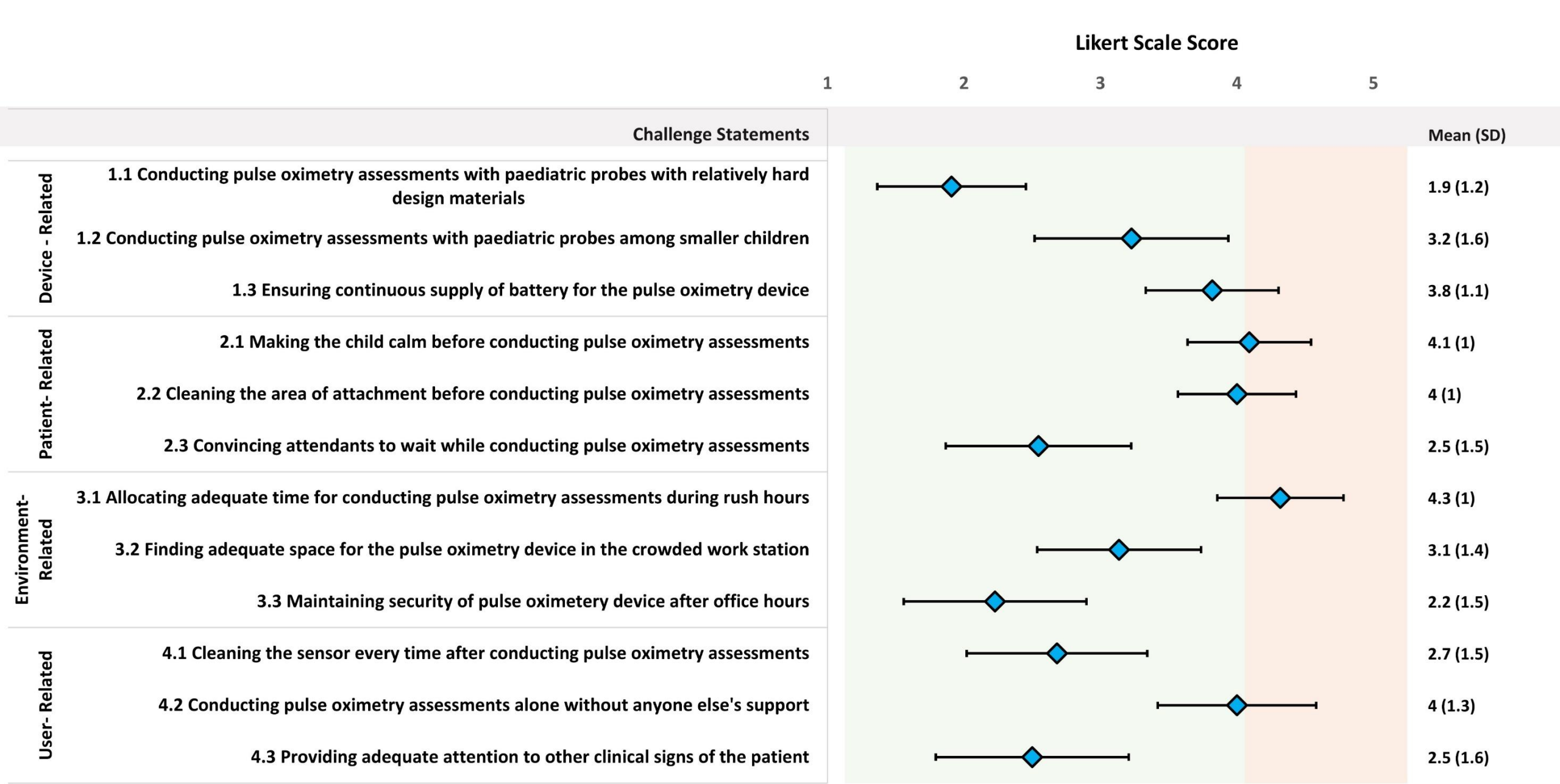
Likert Scale Score
1
2
3
4
5
Challenge Statements
Mean (SD)
Device - Related
1.1 Conducting pulse oximetry assessments with paediatric probes with relatively hard design materials
1.9 (1.2)
1.2 Conducting pulse oximetry assessments with paediatric probes among smaller children
3.2 (1.6)
1.3 Ensuring continuous supply of battery for the pulse oximetry device
3.8 (1.1)
Patient- Related
2.1 Making the child calm before conducting pulse oximetry assessments
4.1 (1)
2.2 Cleaning the area of attachment before conducting pulse oximetry assessments
4 (1)
2.3 Convincing attendants to wait while conducting pulse oximetry assessments
2.5 (1.5)
Environment-Related
3.1 Allocating adequate time for conducting pulse oximetry assessments during rush hours
4.3 (1)
3.2 Finding adequate space for the pulse oximetry device in the crowded work station
3.1 (1.4)
3.3 Maintaining security of pulse oximetery device after office hours
2.2 (1.5)
User- Related
4.1 Cleaning the sensor every time after conducting pulse oximetry assessments
2.7 (1.5)
4.2 Conducting pulse oximetry assessments alone without anyone else's support
4 (1.3)
4.3 Providing adequate attention to other clinical signs of the patient
2.5 (1.6)

Childhood Pneumonia

Introducing pulse oximetry is feasible

Is it effective?

BMJ Open

Pulse oximeter with integrated management of childhood illness for diagnosis of severe childhood pneumonia at rural health institutions in Southern Ethiopia: results from a cluster-randomised controlled trial

Solomon H Tesfaye [1,2,3] Yabibal Gebeyehu,[4] Eskindir Loha,[1,5] Kjell Arne Johansson,[2] Bernt Lindtjørn [1,2]

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► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2020-036814).

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ABSTRACT

Objective To assess whether pulse oximetry improves health workers' performance in diagnosing severe childhood pneumonia at health centres in Southern Ethiopia.

Design Parallel cluster-randomised trial.

Setting Government primary health centres.

Participants Twenty-four health centres that treat at least one pneumonia case per day in Southern Ethiopia. Children aged between 2 months and 59 months who present at health facilities with cough or difficulty breathing were recruited in the study from September 2018 to April 2019.

Intervention arm Use of the Integrated Management of Childhood Illness (IMCI) algorithm and pulse oximeter.

Control arm Use of the IMCI algorithm only.

Primary and secondary outcome measures The primary outcome was the proportion of children diagnosed with severe pneumonia. Secondary outcomes included referred cases of severe pneumonia and treatment failure on day 14 after enrolment.

Result Twenty-four health centres were randomised into intervention (928 children) and control arms (876 children). The proportion of children with severe pneumonia was 15.9% (148 of 928 children) in the intervention arm and 3.9% (34 of 876 children) in the control arm. After adjusting for differences in baseline variables children in the intervention arm were more likely to be diagnosed as severe pneumonia cases as compared with those in the control arm (adjusted OR: 5.4, 95% CI 2.0 to 14.3, p=0.001).

Conclusion The combined use of IMCI and pulse oximetry in health centres increased the number of diagnosed severe childhood pneumonia.

Trial registration number PACTR201807164196402.

Strengths and limitations of this study

- Random allocation of health centres to intervention and control arms.
- Participating health centres were typical of such institutions in rural communities in Ethiopia.
- Robust training on how to use the Integrated Management of Childhood Illness algorithm, and how to measure oxygen saturation.
- Due to the nature of the intervention, inability to mask the health workers and the study participants of the intervention.
- Unequal number of children seeking healthcare between the two comparison arms.

INTRODUCTION

Pneumonia killed approximately 920,000 children aged less than 5 years in 2015.[1] The mortality rate is especially high in Ethiopia, and 59 deaths per 1000 live births occurred in 2017 in children aged less than 5 years.[2] Ethiopia ranks sixth among countries with the highest number of deaths from pneumonia in children aged less than 5 years.[1]

The WHO Integrated Management of Childhood Illness (IMCI) improves the quality of child care for common illnesses,[3 4] but there is poor diagnostic precision for childhood pneumonia based on clinical features.[5] The ability of healthcare providers to count breaths and classify respiratory rate in children using the IMCI algorithm is a challenge.[6]

Clinical signs of pneumonia, such as tachypnoea, inability to drink or breast feed and head-nodding, used in the IMCI algorithm, are not able to identify hypoxic children with severe pneumonia as precisely as pulse oximetry.[7] Consequently, many children with severe pneumonia are dying because hypoxaemia is not adequately recognised and/or oxygen therapy is unavailable.[1]

This study is an extension of a study in which we first assessed the health system support of

Table 3 OR from the multilevel logistic regression model comparing the proportion of diagnosed severe pneumonia between the arms

Variables		Total	Diagnosed severe pneumonia n (%)	Bivariate analysis COR* (95% CI)	Multivariable analysis AOR† (95% CI)	P value
Intervention‡	Yes	928	148 (15.9)	4.7 (1.9 to 11.8)	5.4 (2.0 to 14.3)	0.001
	No	876	34 (3.9)	1	1	
Sex of child	Boy	954	113 (11.8)	1.9 (1.1 to 3.1)	1.5 (1.1 to 2.3)	0.033
	Girl	830	69 (8.3)	1	1	
Age of child (months)	2–11	773	93 (12.0)	1.7 (1.2 to 2.4)	1.7 (1.1 to 2.6)	0.011
	12–59	1031	89 (8.6)	1	1	
Height-for-age z-score (<−2)	Yes	763	87 (11.4)	1.5 (1.0 to 2.3)	1.5 (1.0 to 2.3)	0.055
	No	914	73 (8.0)	1	1	
Pneumococcal and *Haemophilus influenzae* type b vaccines	Partially vaccinated	469	67 (14.3)	2 (1.3 to 3.0)	1.7 (1.1 to 2.7)	0.043
	Fully vaccinated	1335	115 (8.6)	1	1	
Educational status of parents	No education	823	96 (11.7)	1.7 (0.9 to 3.3)	1.1 (0.5 to 2.3)	0.797
	Primary	803	72 (9.0)	1.4 (0.7 to 2.6)	1.3 (0.6 to 2.6)	0.487
	Secondary	176	14 (8.0)	1	1	
Wealth tertiles	Poor	539	52 (9.6)	1.7 (0.8 to 3.3)	1.1 (0.7 to 1.9)	0.617
	Medium	521	47 (9.0)	1.3 (0.8 to 2.3)	0.9 (0.6 to 1.5)	0.761
	Rich	559	58 (10.4)	1	1	

*Crude OR.
†Adjusted OR.
‡The intraclass correlation coefficient for severe pneumonia was 0.043.

World Pneumonia Day 2022

PLOS GLOBAL PUBLIC HEALTH

RESEARCH ARTICLE

Cost-effectiveness of pulse oximetry and integrated management of childhood illness for diagnosing severe pneumonia

Solomon H. Tesfaye[1,2,3]*, **Eskindir Loha**[1,2], **Kjell Arne Johansson**[2], **Bernt Lindtjørn**[1,2]

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Abstract

Pneumonia is a major killer of children younger than five years old. In resource constrained health facilities, the capacity to diagnose severe pneumonia is low. Therefore, it is important to identify technologies that improve the diagnosis of severe pneumonia at the lowest incremental cost. The objective of this study was to conduct a health economic evaluation of standard integrated management of childhood illnesses (IMCI) guideline alone and combined use of standard IMCI guideline and pulse oximetry in diagnosing childhood pneumonia. This is a cluster-randomized controlled trial conducted in health centres in southern Ethiopia. Two methods of diagnosing pneumonia in children younger than five years old at 24 health centres are analysed. In the intervention arm, combined use of the pulse oximetry and standard IMCI guideline was used. In the control arm, the standard IMCI guideline alone was used. The primary outcome was cases of diagnosed severe pneumonia. Provider and patient costs were collected. A probabilistic decision tree was used in analysis of primary trial data to get incremental cost per case of diagnosed severe pneumonia. The proportion of children diagnosed with severe pneumonia was 148/928 (16.0%) in the intervention arm and 34/876 (4.0%) in the control arm. The average cost per diagnosed severe pneumonia case was USD 25.74 for combined use of pulse oximetry and standard IMCI guideline and USD 17.98 for standard IMCI guideline alone. The incremental cost of combined use of IMCI and pulse oximetry was USD 29 per extra diagnosed severe pneumonia case compared to standard IMCI guideline alone. Adding pulse oximetry to the diagnostic toolkit in the standard IMCI guideline could detect and treat one more child with severe pneumonia for an additional investment of USD 29. Better diagnostic tools for lower respiratory infections are important in resource-constrained settings, especially now during the COVID-19 pandemic.

Introduction

Pneumonia is a leading cause of death among children younger than five years old [1]. Childhood pneumonia is associated with chronic obstructive pulmonary disease, reduced lung

Table 1. Unit cost of items for pneumonia diagnosis and treatment, 2018 USD.

Items	Unit costs	
Diagnosis	Intervention arm	Control arm
Pulse oximetry	149.81	Not applicable
Batteries	1.01	Not applicable
Personnel	0.59	0.34
Training	13.96	7.40
Oxygen treatment (per cubic meter)	0.77	0.77
Patient expense		
Drugs	1.01	1.01
Intravenous fluids	0.88	0.88
Intravenous cannula 24 gages	0.34	0.34
Hospital stay	1.18	1.18
Consultation	0.40	0.40
Transportation per kilometre	0.03	0.03

https://doi.org/10.1371/journal.pgph.0000757.t001

Table 3. Total and average cost for diagnosed pneumonia cases, 2018 USD.

Diagnostic alternatives	Severe pneumonia			non-severe pneumonia		
	Number diagnosed	Total cost (USD)	Average cost (USD)	Number diagnosed	Total cost (USD)	Average cost (USD)
Standard IMCI alone	34	611.30	17.98	842	1800.17	2.14
Standard IMCI and pulse oximetry combined	148	3809.24	25.74	780	2794.45	3.58

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World Pneumonia Day 2022

ARTICLE OPEN

Evaluating the impact of pulse oximetry on childhood pneumonia mortality in resource-poor settings

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It is estimated that pneumonia is responsible for 15% of childhood deaths worldwide. Recent research has shown that hypoxia and malnutrition are strong predictors of mortality in children hospitalized for pneumonia. It is estimated that 15% of children under 5 who are hospitalized for pneumonia have hypoxaemia and that around 1.5 million children with severe pneumonia require oxygen treatment each year. We developed a deterministic compartmental model that links the care pathway to disease progression to assess the impact of introducing pulse oximetry as a prognostic tool to distinguish severe from non-severe pneumonia in under-5 year olds across 15 countries with the highest burden worldwide. We estimate that, assuming access to supplemental oxygen, pulse oximetry has the potential to avert up to 148,000 deaths if implemented across the 15 countries. By contrast, integrated management of childhood illness alone has a relatively small impact on mortality owing to its low sensitivity. Pulse oximetry can significantly increase the incidence of correctly treated severe cases as well as reduce the incidence of incorrect treatment with antibiotics. We also found that the combination of pulse oximetry with integrated management of childhood illness is highly cost-effective, with median estimates ranging from US$2.97 to $52.92 per disability-adjusted life year averted in the 15 countries analysed. This combination of substantial burden reduction and favourable cost-effectiveness makes pulse oximetry a promising candidate for improving the prognosis for children with pneumonia in resource-poor settings.

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Despite interventions being available, it is estimated that pneumonia is responsible for 15% of childhood deaths worldwide[1]. Reductions in annual mortality remain modest, with nearly 950,000 under-5 year olds dying of pneumonia in 2013 (ref. 2). Despite the unprecedented rate of *Haemophilus influenzae* type B (Hib) and pneumococcal vaccine (PCV) introduction, achieving high levels of coverage in developing countries is still challenging[3]. Therefore, in regions where vaccine introduction and scale-up lags behind other countries, improved access to diagnosis and treatment is crucial. This includes interventions at multiple points in the continuum of care — improving care-seeking practices, increasing the availability of suitable diagnostics, and guiding both formal and informal care providers in appropriate disease management. Unfortunately, current treatment coverage remains low, and, more importantly, most childhood pneumonia deaths result from a lack of, or delay in, accurate diagnosis[4].

A crucial component of improving pneumonia outcomes is the early identification of patients at risk of treatment failure and the timely provision of supportive care. However, in the absence of appropriate prognostic tools at the frontline, currently recommended World Health Organization (WHO) guidelines for integrated management of childhood illness (IMCI) often lead to an overuse of antibiotics and the under-referral of patients with severe pneumonia who require hospital care[5]. The most recent 2015 technical update of IMCI guidelines defines non-severe pneumonia as the presence of fast breathing or chest in-drawing or both, which is treatable with oral antibiotics. Severe pneumonia is defined as cough or difficulty breathing in the presence of danger signs, and requires referral to a hospital or health facility for injectable antibiotics or other supportive care such as oxygen therapy[6]. Currently, identification of these IMCI symptoms remains inconsistent and unreliable among community health-care workers or carers without clinical training[7]. Therefore, improved prognostic and diagnostic tools for case-management are necessary to substantially reduce pneumonia-associated morbidity and mortality.

Hypoxaemia and malnutrition are strong predictors of mortality in children who are hospitalized for pneumonia[8,9]. This has led to increasing support for the use of oxygen therapy and monitoring oxygen saturation in the management of severe cases. It is estimated that 15% of children who are hospitalized for pneumonia have hypoxaemia (oxygen saturation, or SpO2, of <90% (ref. 10) and that around 1.5 million children with severe pneumonia require oxygen treatment each year[1]. The use of pulse-oximetry devices (used to measure the oxygen level in the blood) in community health-care settings has been proposed as a method to identify hypoxic children at risk of treatment failure. These devices may be particularly beneficial at the frontline given that they require little training and reduce the reliance on clinical symptoms. The current pulse-oximetry systems are also quick, non-invasive and require minimal infrastructure.

The aim of this study was to evaluate the public health impact and cost-effectiveness of current IMCI guidelines combined with pulse-oximetry devices as a prognostic tool in the hands of frontline health workers in resource-poor settings. To do this, we developed a model of disease progression

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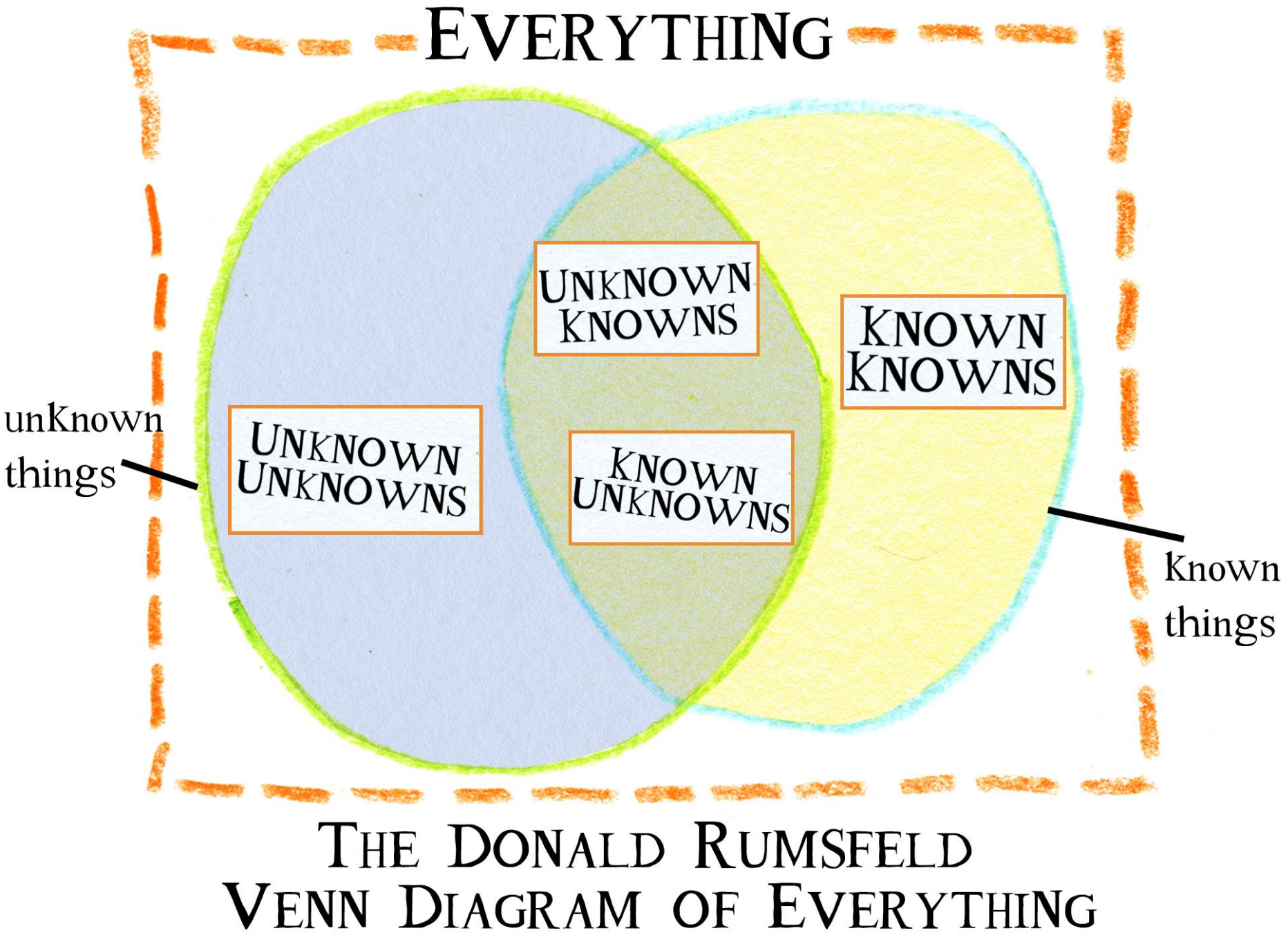
✓ Pulae oximetry has the potential to **avert up to 148,000 deaths** if implemented across the high burden 15 countries

✓ **Pulse oximetry with IMCI is highly cost-effective**, with US$2.97 to $52.92 per DALY averted

Childhood Pneumonia

Introducing pulse oximetry is recommended

It is effective…it can have a big impact



THE DONALD RUMSFELD VENN DIAGRAM OF EVERYTHING

Ahmed Ehsanur Rahman

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