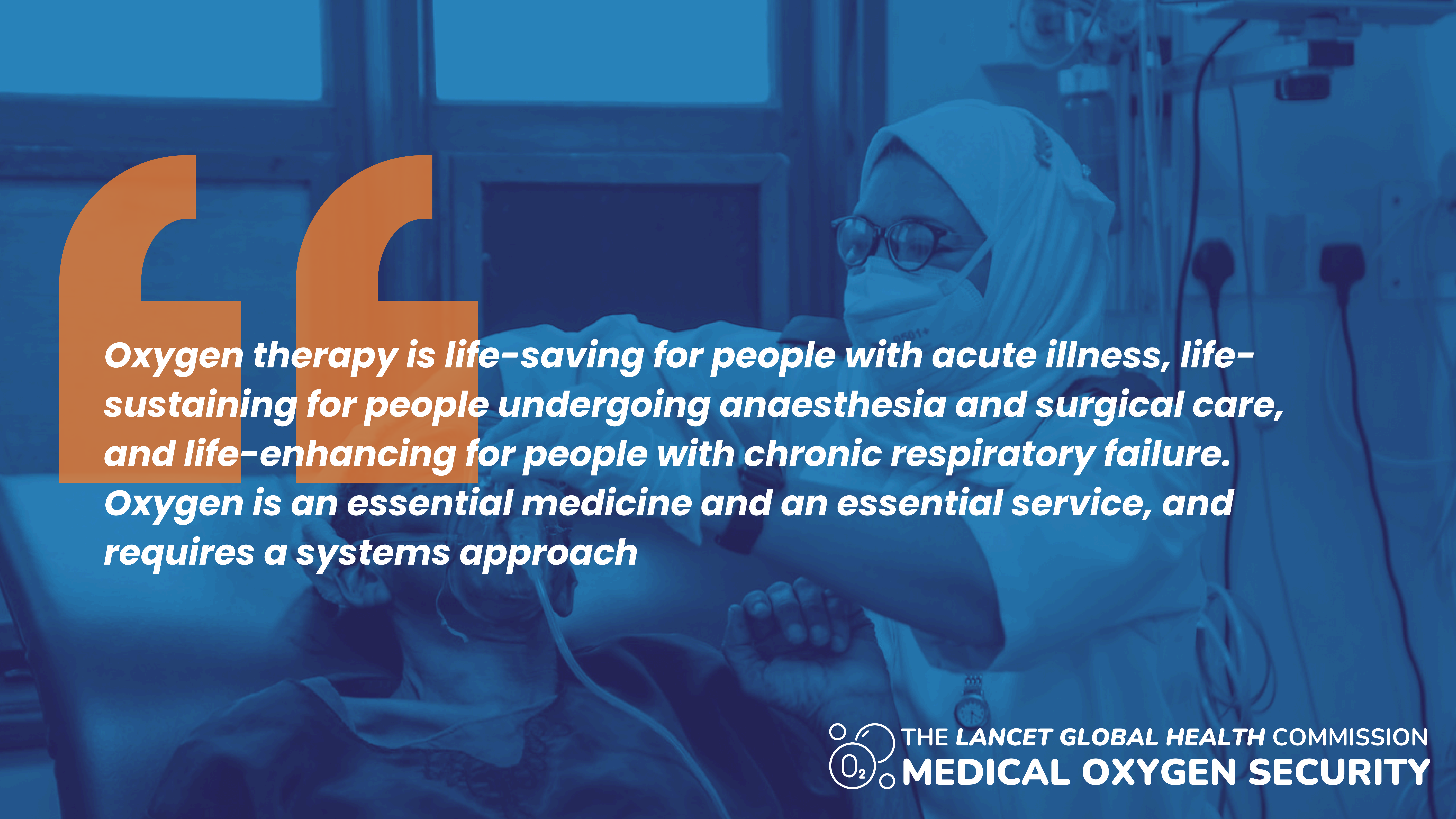
THE LANCET Global Health

COMMISSION ON MEDICAL OXYGEN SECURITY

Reducing global inequities in medical oxygen access:

The Lancet Global Health Commission on Medical Oxygen Security

OFFICIAL DECK


Oxygen therapy is life-saving for people with acute illness, life-sustaining for people undergoing anaesthesia and surgical care, and life-enhancing for people with chronic respiratory failure. Oxygen is an essential medicine and an essential service, and requires a systems approach
THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

A short history of medical oxygen

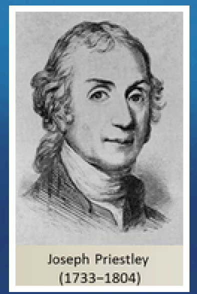
Oxygen is a life-saving therapy that is more than 100 years old, yet is not available for most people

"Fire air" (oxygen) discovered by Scheele, Sweden

1771

1774

"Dephlogisticated air" (oxygen) discovered by Priestley, UK



First recorded oxygen of woman with TB by Caillens, France

1783

1796

Vaccination (smallpox) discovered by Jenner, UK

1800's access to medical oxygen "dark ages"

Young pneumonia patient treated with oxygen by Holtzapple, USA

1885

1895

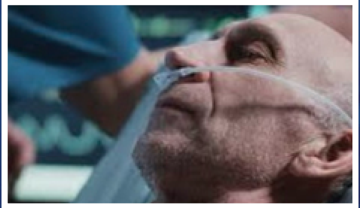
X-rays discovered by Röntgen, Germany

Air separation plants developed by Linde and Claude, France

1902

1907

Nasal catheters developed by Lane, UK



1900's innovations did not benefit regions outside of Europe and North America

Penicillin discovered by Fleming, UK

1928

1955

Long-term oxygen therapy pioneered by Petty, Australia

Blood gas analyzers invented by Severinghaus, USA

1957

1960

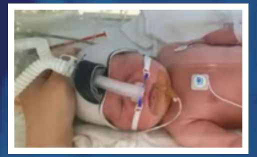
PSA plant technology developed by Skarstrom, USA

Pulse oximetry invented by Aoyagi, Japan

1974

1979

Home oxygen concentrators produced by Union Carbide, USA

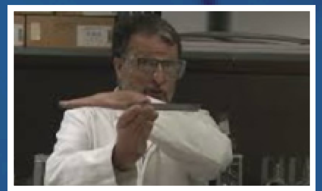


CPAP invented by Sullivan, Australia

1980

2020

M-COG invented at NASA by Graf, USA



THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

COVID-19 wake up call

Pandemic emergency oxygen response was slow but grew

ACT-A Oxygen Emergency Taskforce

- Over US$1 billion mobilized
- Emergency response large but challenging

It is unlikely that oxygen would have been neglected if low- and middle-income country representatives were included in ACT-A.

External Evaluation of ACT-A, October 2022

Post-pandemic opportunity to sustain and build on pandemic investments

- New coordination body → Global Oxygen Alliance (GO_2AL)
- New global resolution → WHO resolution (WHA76.3)
- New actors and innovation in practice and policy

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

A Lancet Commission

A scientific review, inquiry, and response to an urgent, and perhaps neglected or understudied, health predicament

- Science-led
- International collaboration
- Multidisciplinary
- Aims for (transformational) change
- Focused on policy and/or political action
- Report of no more than 20,000 words and 250 references
- Published in regular journal and printed as a stand-alone booklet
- Around two years in the making

Sep 2022

Kitutu, F. E., et al. (2022). "Announcing the Lancet Global Health Commission on medical oxygen security." The Lancet Global Health.

Comment

Announcing the *Lancet Global Health* Commission on medical oxygen security

Published Online
September 23, 2022
https://doi.org/10.1016/S2214-109X(22)00407-7

Medical oxygen is an essential health treatment for both acute and chronic conditions across all age groups. Strong medical oxygen systems save lives. Therefore, adequate access to safe, affordable, and appropriate medical oxygen services is crucial for improving population health and meeting the Sustainable Development Goal targets. However, severely limited or unreliable oxygen services have been a persistent issue in many low-income and middle-income countries (LMICs), particularly among small health facilities serving poor, rural, and otherwise marginalised populations.

Medical oxygen insecurity has been a defining inequity of the COVID-19 pandemic, with LMICs bearing the worst of oxygen-related disruptions and excess mortality. Millions of health-care workers and families have experienced the desperation of trying to find oxygen for severely unwell patients and family members. We might never know how many COVID-19 deaths resulted from a lack of access to oxygen during the pandemic, but the limited data available suggest that it is substantial. For example, a study of COVID-19 deaths in 64 intensive care units across ten African countries showed that one in two patients died without receiving medical oxygen,[1] with the situation likely to be worse in smaller, less-resourced hospitals.

Although COVID-19 exposed and exacerbated a massive underlying gap in access to medical oxygen across LMICs, it also resulted in unprecedented attention to, and investment in, oxygen systems that can benefit many patients. Severe COVID-19 is just one indication for medical oxygen therapy. Other notable indications include neonates in respiratory distress; infections including pneumonia, malaria, sepsis, and tuberculosis; chronic illnesses including chronic obstructive pulmonary disease, heart disease, and asthma; and surgery and trauma care. Data suggest that this cumulative need is massive and largely underserved.[2,3] For example, an estimated 7 million children with hypoxaemic pneumonia alone needing medical oxygen therapy are admitted to LMIC hospitals each year,[4] yet in many contexts only one in five actually receives it.[5]

Health-care personnel and patients in many LMICs have experienced the medical oxygen crisis as a painful reality for many years, frustrating efforts to provide quality care, forcing choices about who to prioritise, and burdening patients with treatment costs. But it has taken a global respiratory disease pandemic to draw the attention of the global community. With support from the Access to COVID-19 Tools Accelerator Oxygen Emergency Task Force, and other donors, many LMICs have received new oxygen technologies (eg, liquid, pressure swing adsorption plants, mobile concentrators, pulse oximeters, continuous positive airway pressure devices, ventilators, etc) to treat patients with COVID-19. However, radical improvements in underlying support structures, processes, and personnel are needed if these are to be sustainably integrated into health systems, alongside surge capacity, to achieve a long-lasting effect on lives.

Figure: Four key research themes and pillars

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

The team

Sep 2022

Feb 2025

Commissioners

18 academic experts

Consultations

- Industry
- Health ministries
- Patients and caregivers

Executive

5 institutions

icddr,b
Makerere University
murdoch children's research institute
Karolinska Institutet
Every Breath Counts

Photo: Lancet Global Health

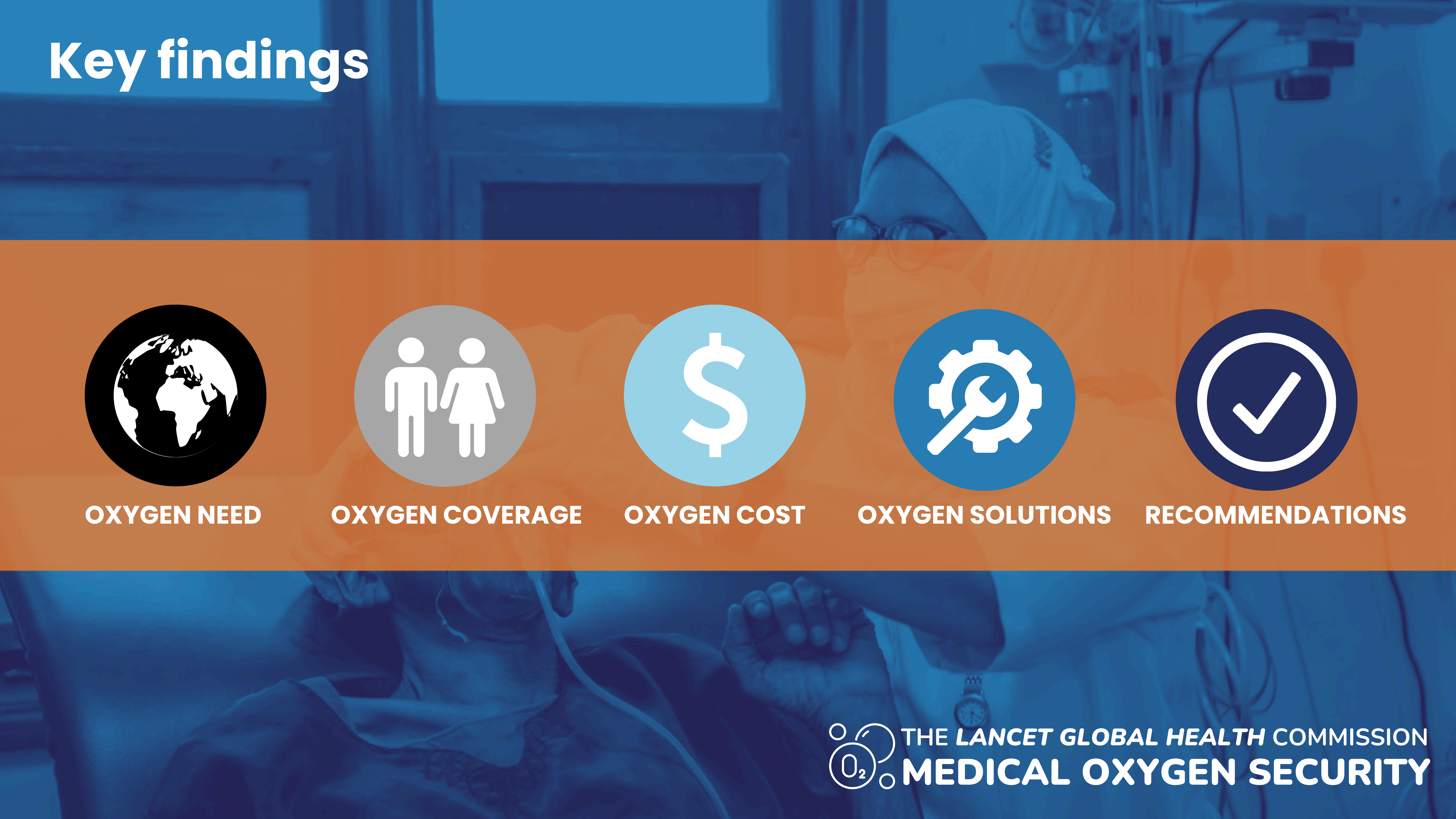
Photo: Lancet Global Health

Advisors

40 stakeholders from diverse sectors

Oxygen Access Collaborators

100+ global network


Key findings
OXYGEN NEED
OXYGEN COVERAGE
OXYGEN COST
OXYGEN SOLUTIONS
RECOMMENDATIONS
THE LANCET GLOBAL HEALTH COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen need

Each year, 374 million people need medical oxygen: 306 million (82%) live in low- and middle-income countries (LMICs). During emergencies, the need for oxygen can rise exponentially, putting enormous pressure on health systems

Global medical oxygen need

Who needs oxygen?

374 million people

306 million (82%) live in LMICs

- 30% (93 million) in South Asia
- 29% (88 million) in East Asia & Pacific
- 24% (72 million) in Sub-Saharan Africa
- 8% (24 million) in Latin America & Caribbean
- 5% (17 million) in Middle East & North Africa
- 4% (12 million) in Europe & Central Asia

4.6 billion cubic meters (Nm3)

- 1·2 billion Nm3 for acute medical and surgical (see Figure 1)
- 3.2 billion Nm3 for COPD (not on Figure 1)

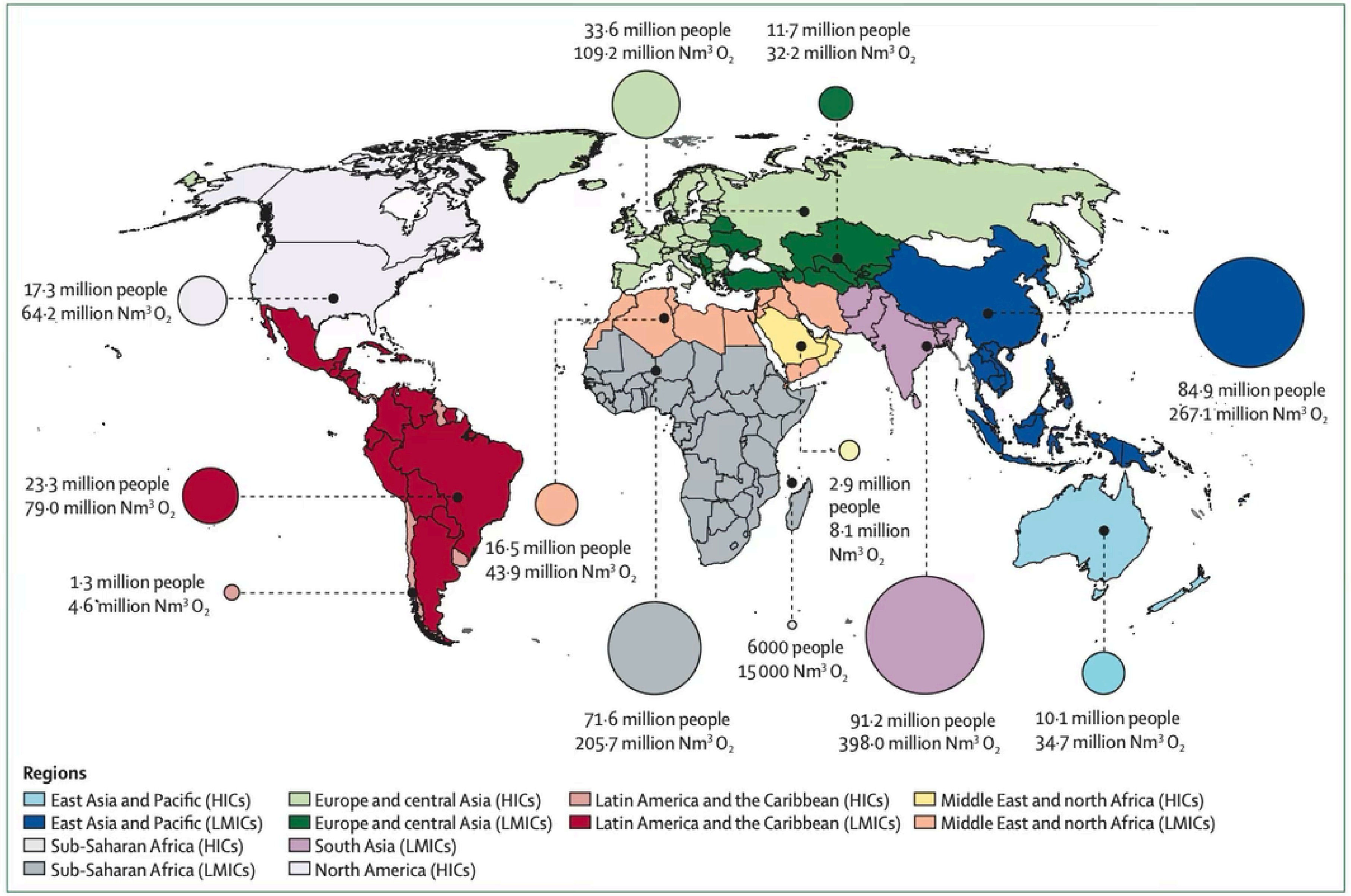


Figure 1: **Location of people with acute medical and surgical oxygen needs in 2021, and minimum volume of oxygen required to meet need, by World Bank region**
Note that this figure excludes oxygen requirements related to COVID-19. Oxygen need is represented by the circles, the sizes of which are proportional to the number of people in that region who need medical oxygen therapy. Minimum volume of oxygen required to meet need was calculated using data for recommended and usual flow rates and duration for various conditions and assumes no inefficiencies in oxygen use and no wastage or inefficiencies in upstream oxygen production, supply, and distribution. HICs=high-income countries. LMICs=low-income and middle-income countries. Nm^3=normal cubic metres.

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Global medical oxygen need

Who needs oxygen?

People with acute conditions (cardiovascular diseases, respiratory and other infections, neonatal disorders, trauma, and more): 105.4 million excluding COVID-19 (see Table 2)

People with chronic conditions (COPD): 9.2 million

People needing surgery: 259 million

I remember when I got to the emergency room my saturation was 80%. I had a blackout in front of my eyes. I thought I would die. I was sweating. I felt like there was no life in my hands or feet. I felt much better when I got on oxygen and my symptoms got better and I thought I would come out of it. It gave me hope.

Young patient in respiratory failure, Pakistan

	People with acute hypoxaemia needing oxygen, millions (uncertainty interval)	Minimum oxygen volume to meet acute hypoxaemia need, millions of Nm³ (uncertainty interval)
Neonatal encephalopathy	0·5 (0·2–0·8)	1·0 (0·5–1·7)
Neonatal lower respiratory infections	0·7 (0·1–1·6)	1·6 (0·3–3·6)
Preterm birth	3·2 (1·7–4·9)	12·6 (6·9–19·6)
Neonatal sepsis and other infections	1·0 (0·5–1·5)	2·2 (1·2–3·4)
Asthma	2·5 (0·6–5·6)	27·8 (8·2–60·8)
Diarrhoea	6·4 (1·7–15·0)	57·6 (15·3–133·4)
HIV/AIDS	1·1 (0·6–1·9)	19·5 (10·9–32·8)
Malaria	3·8 (1·4–8·6)	21·6 (8·4–47·7)
Nutritional deficiencies	1·3 (0·4–3·1)	5·2 (1·6–12·1)
Encephalitis	0·4 (0·2–0·7)	5·7 (2·7–10·1)
Meningitis	0·5 (0·2–1·0)	6·6 (2·8–13·2)
Lower respiratory infections	24·7 (11·5–44·4)	357·5 (147·1–676·1)
Trauma or injury	17·4 (5·8–36·5)	199·0 (63·5–421·5)
Tuberculosis	0·9 (0·3–1·8)	13·5 (4·7–29·7)
Typhoid	0·1 (0·0–0·3)	0·8 (0·3–1·7)
Dengue	0·7 (0·1–2·2)	6·5 (0·7–21·9)
Measles and pertussis	1·5 (0·7–3·0)	6·0 (2·6–11·8)
Cardiovascular disease	26·7 (8·4–56·3)	243·6 (76·4–513·3)
Sepsis (not otherwise classified)	4·7 (2·7–6·9)	70·6 (41·3–104·4)
COVID-19	52·4 (25·1–89·8)	1913·2 (910·8–3284·8)
Other conditions	7·6 (2·4–14·9)	73·0 (23·1–145·3)
Overall	157·8 (64·6–300·8)	3045·2 (1329·4–5549·0)

The minimum volume of oxygen required to meet need was calculated using data for recommended and usual flow rates and duration for various conditions and assumes no inefficiencies in oxygen use and no wastage or inefficiencies in upstream oxygen production, supply, and distribution. We have converted the oxygen gaseous flow rates and duration that we calculated to volume in Nm³, but true volume will depend on actual pressure and temperature. Nm³=normal cubic metres.

Table 2: **Estimated number of patients needing oxygen for acute medical conditions globally and minimum volume of oxygen required to meet need, 2021**

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Global medical oxygen need

Who needs oxygen?

Public health emergencies

- Rapidly increase oxygen need (e.g., respiratory pandemics, mass trauma)
- Destroy health facility and oxygen infrastructure (e.g., conflict)
- Restrict access (e.g., natural disasters)

In 2021, 52 million people with COVID-19 needed oxygen

Photo: Global Fund

When we arrived, there were a lot of patients - it was very crowded - but they took us in and gave [my husband] an oxygen mask and big green cylinder. Five to six patients were sharing one cylinder.

Wife of elderly man with COVID-19, Philippines

Global medical oxygen need

Who needs oxygen?

Increasing need

- Extra 33 million patients (9%) with acute medical and surgical need since 2010 (see Figure 2, A)
- Extra 2.3 million patients (33%) needing long-term oxygen therapy for COPD (see Figure 2, B)

Prevention of need is important

- Reducing smoking, drug and alcohol use, malnutrition, air pollution, accidents and injuries
- Increasing immunization, healthy diets, clean energy, road safety

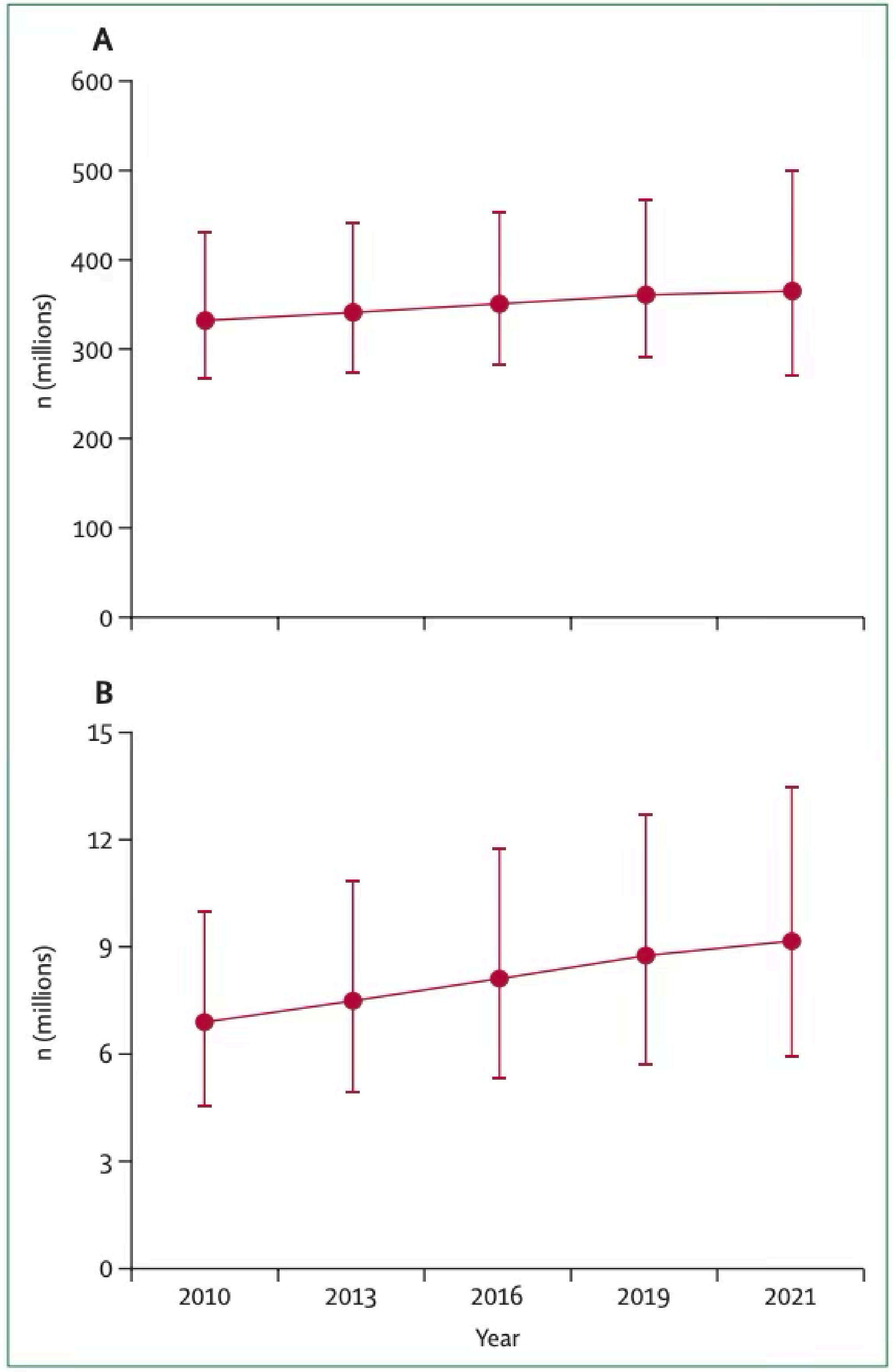
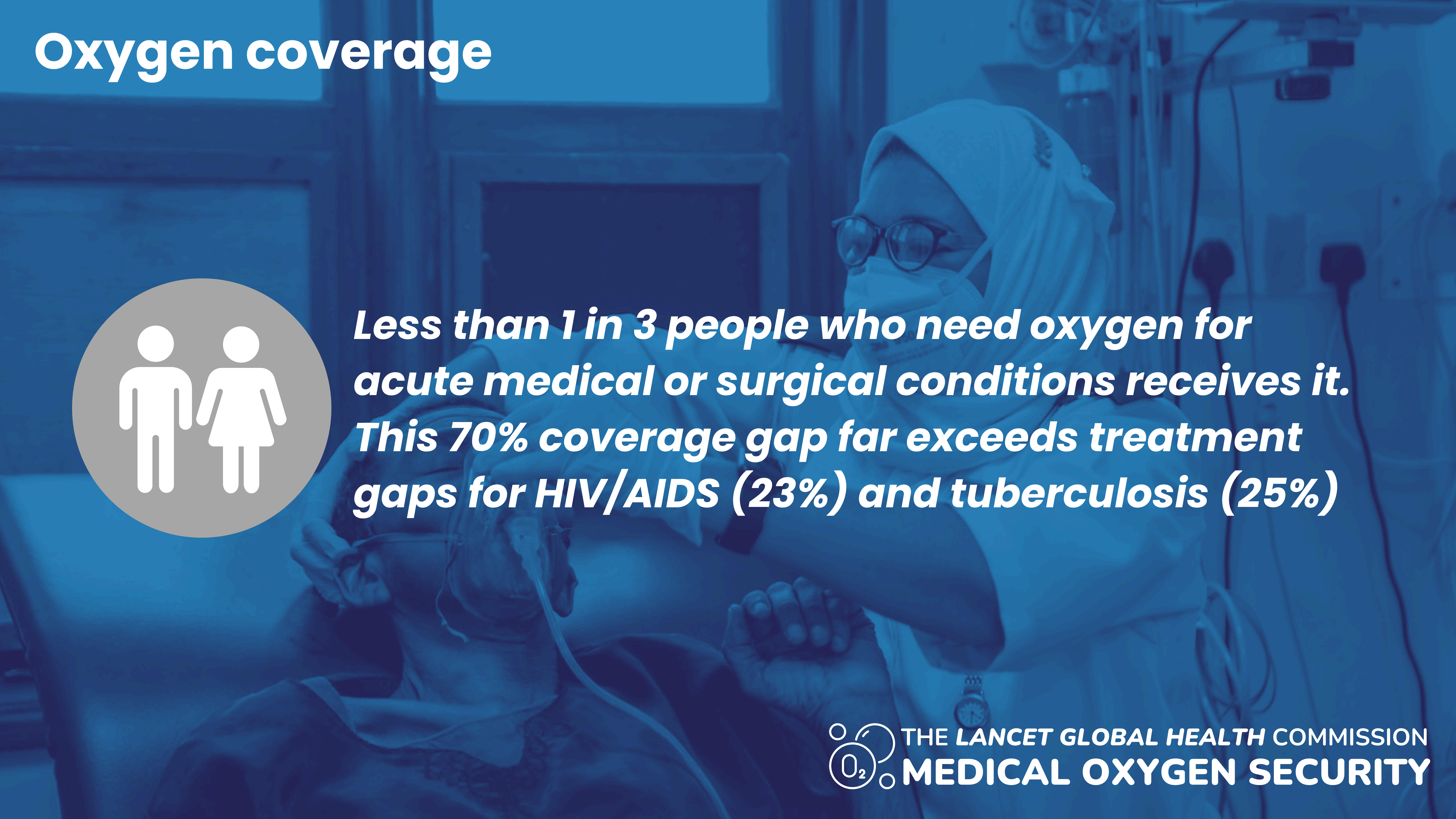


Figure 2: **Trends in estimated global oxygen need (2010–21) for acute medical and surgical oxygen therapy (A) and long-term oxygen therapy (B)**
Data are from the Global Burden of Disease.[63] Oxygen need related to COVID-19 is excluded. Error bars represent uncertainty intervals.

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

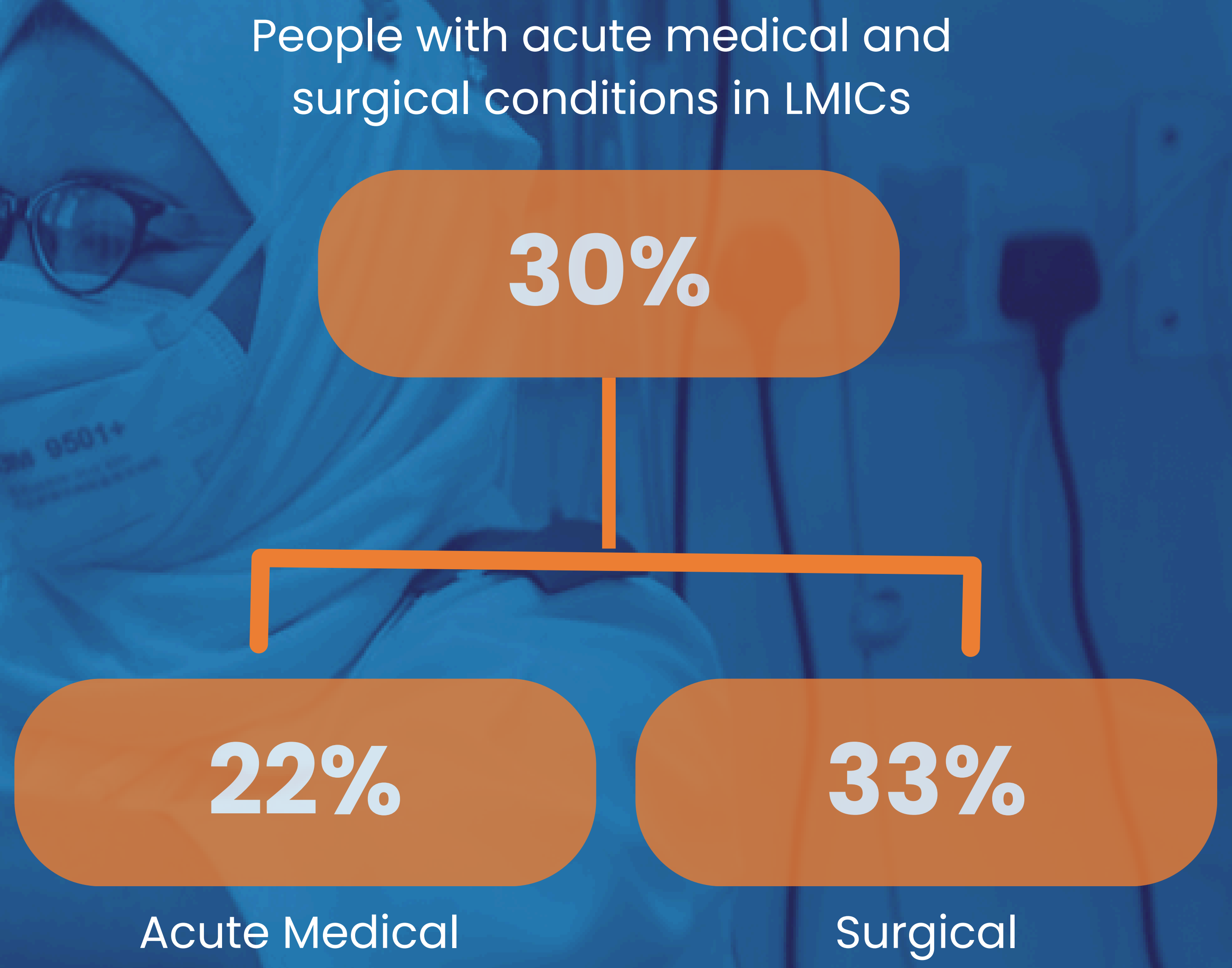

Oxygen coverage
Less than 1 in 3 people who need oxygen for acute medical or surgical conditions receives it. This 70% coverage gap far exceeds treatment gaps for HIV/AIDS (23%) and tuberculosis (25%)
THE LANCET GLOBAL HEALTH COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen coverage gaps

Who receives oxygen in LMICs?

In LMICs, less than 1 in 3 people who need oxygen receive it

- 30% coverage for people with acute medical and surgical conditions (89 of 299 million)
- 22% coverage for people with acute medical conditions (20 of 87 million)
- 33% coverage for people with surgical conditions (70 of 212 million)
- Long-term oxygen therapy not included

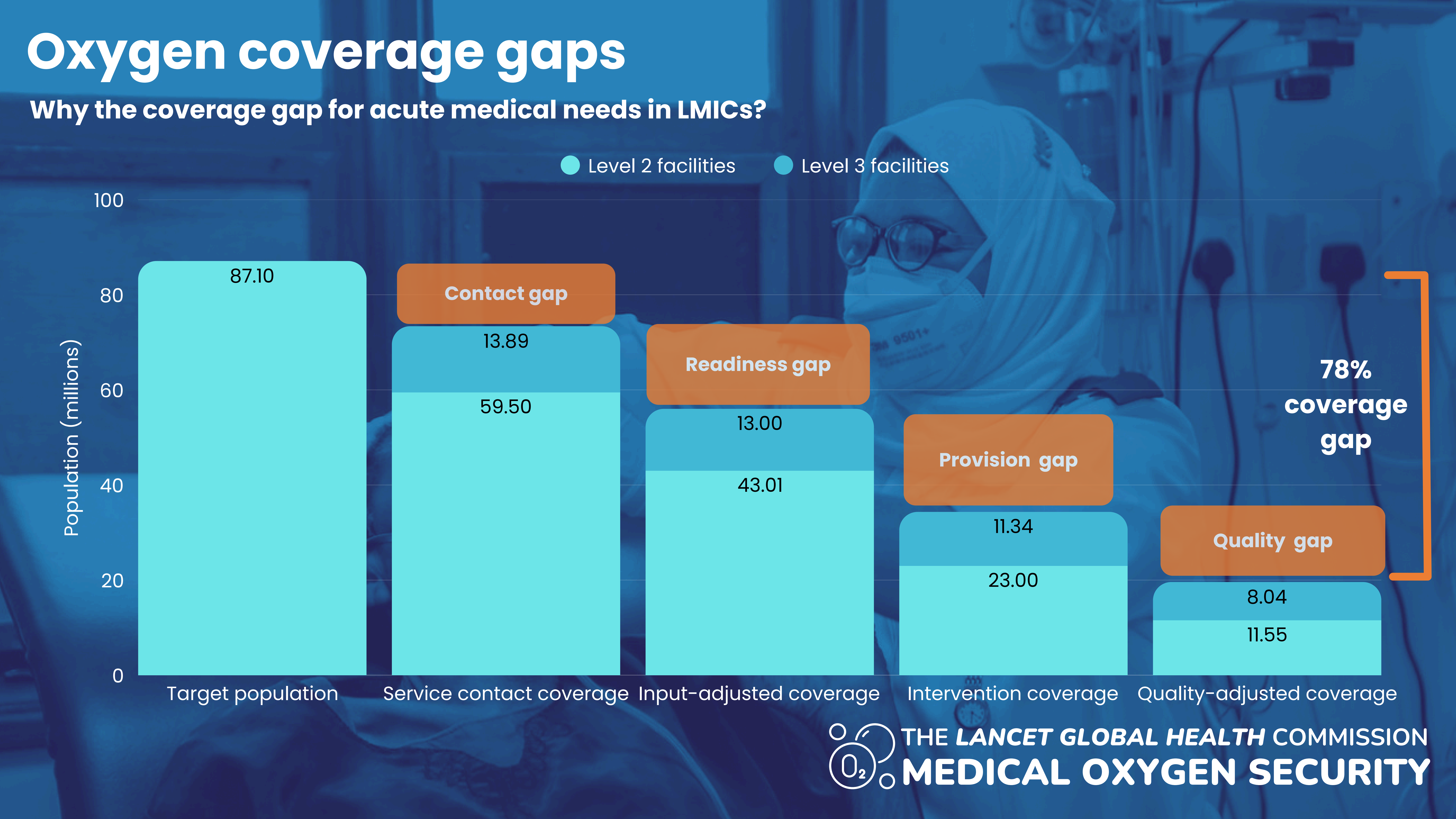


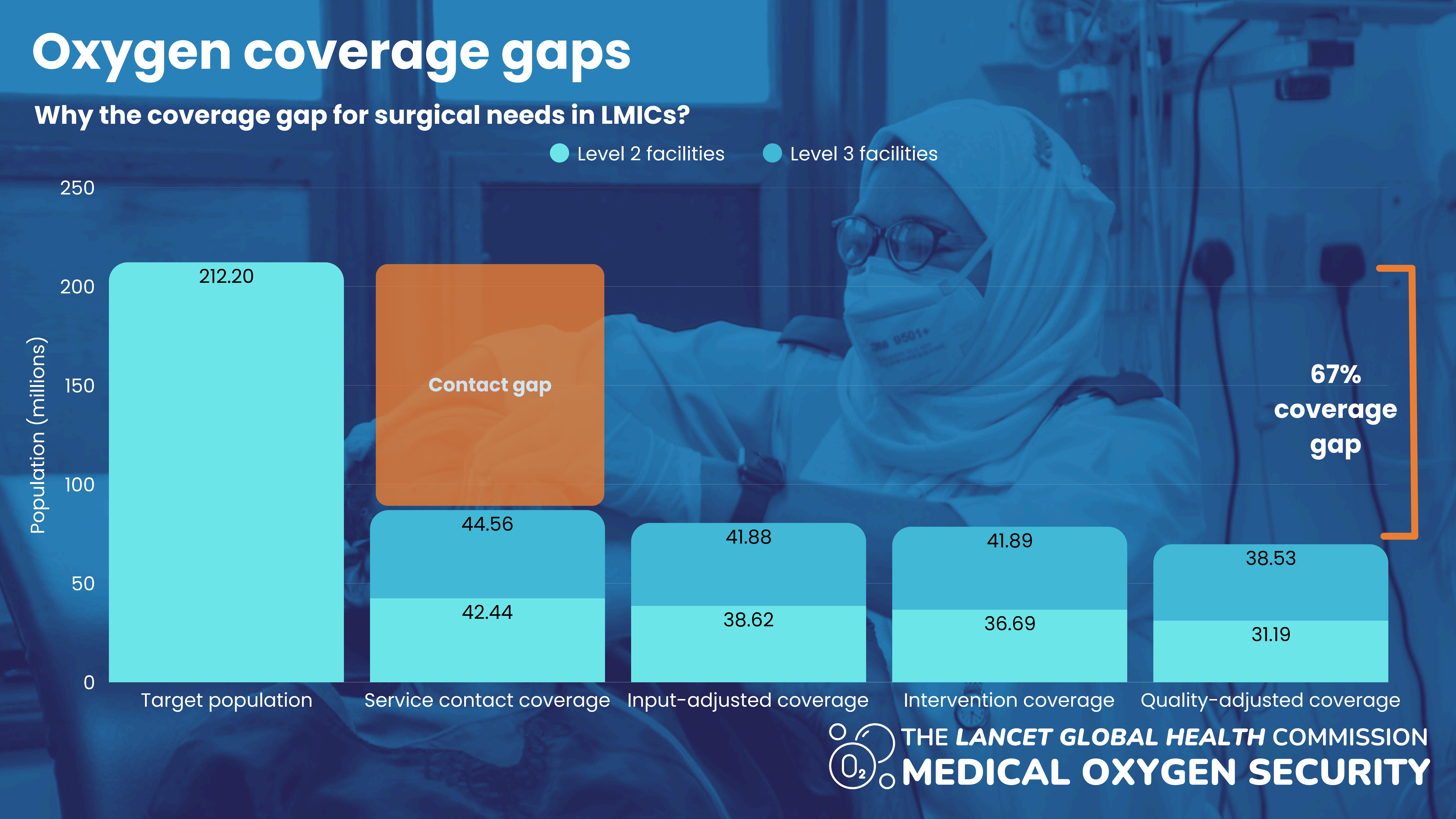
In contrast, more than 3 in 4 people with HIV/AIDS or TB in LMICs get treated

- 75% coverage of TB medicines (1)
- 77% coverage of AIDS medicines (2)

1) Global tuberculosis report 2024, WHO 2024
2) AIDS at a crossroads: 2024 global AIDS update, UNAIDS 2024.

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY


Oxygen coverage gaps
Why the coverage gap for acute medical needs in LMICs?
Level 2 facilities
Level 3 facilities
Population (millions)
100
80
60
40
20
0
87.10
Contact gap
13.89
59.50
Readiness gap
13.00
43.01
Provision gap
11.34
23.00
Quality gap
8.04
11.55
78% coverage gap
Target population
Service contact coverage
Input-adjusted coverage
Intervention coverage
Quality-adjusted coverage
THE LANCET GLOBAL HEALTH COMMISSION
MEDICAL OXYGEN SECURITY


Oxygen coverage gaps
Why the coverage gap for surgical needs in LMICs?
Level 2 facilities
Level 3 facilities
250
200
150
100
50
0
Population (millions)
212.20
Contact gap
44.56
42.44
41.88
38.62
41.89
36.69
38.53
31.19
67% coverage gap
Target population
Service contact coverage
Input-adjusted coverage
Intervention coverage
Quality-adjusted coverage
THE LANCET GLOBAL HEALTH COMMISSION
MEDICAL OXYGEN SECURITY

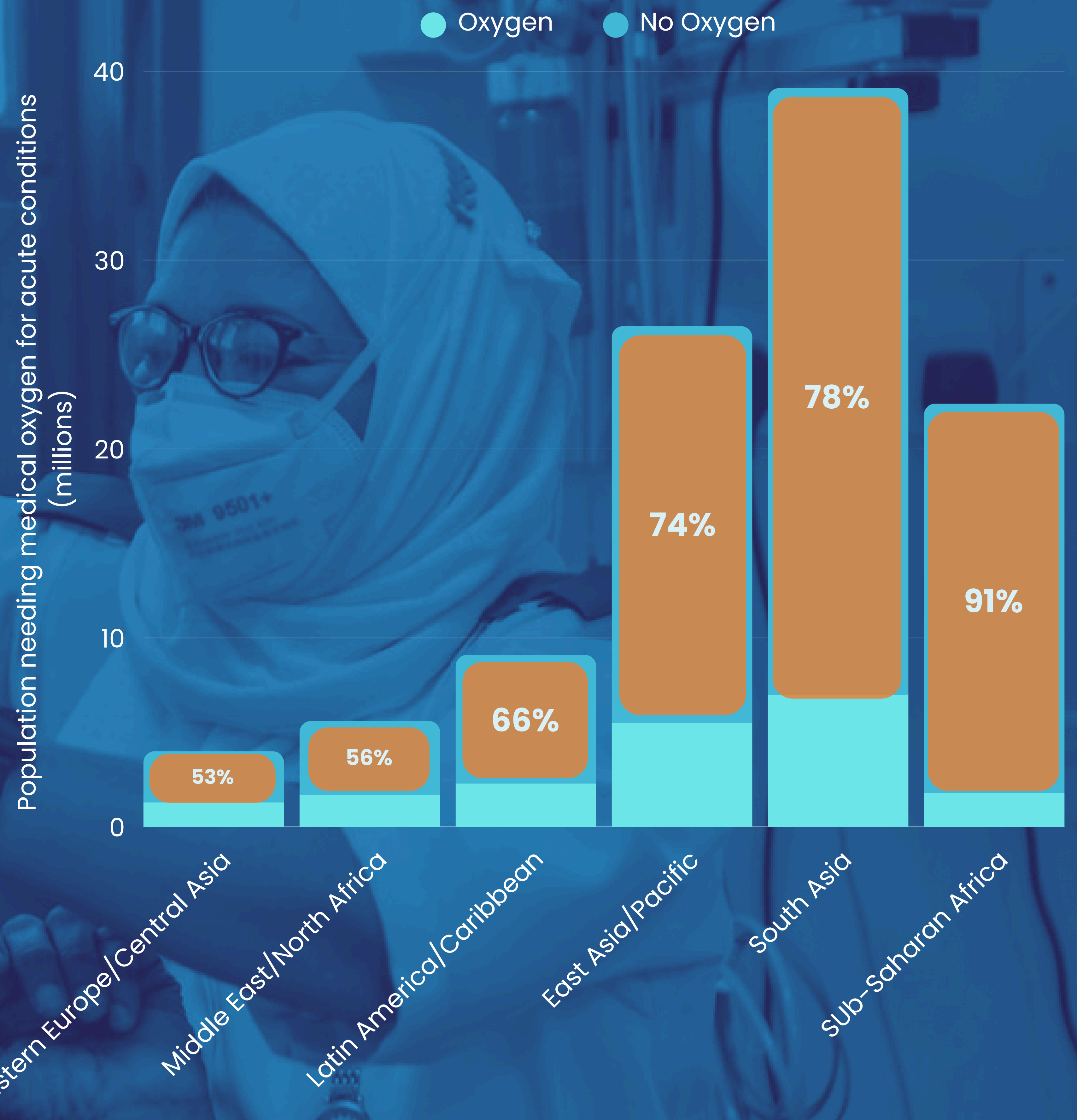
Oxygen coverage gaps

Regional differences in medical oxygen coverage

Deep regional inequities in oxygen coverage for patients with acute medical conditions

- 9% of patients in Sub-Saharan Africa (1.8 of 20.6 million)
- 22% of patients in South Asia (7 of 32.1 million)
- 26% of patients in East Asia and Pacific (5.5 of 21 million)
- 34% of patients in Latin American and Caribbean (2.3 of 6.8 million)
- 44% of patients in the Middle East and North Africa (1.7 of 3.9 million)
- 47% of patients in Eastern Europe & Central Asia (1.3 of 2.7 million)

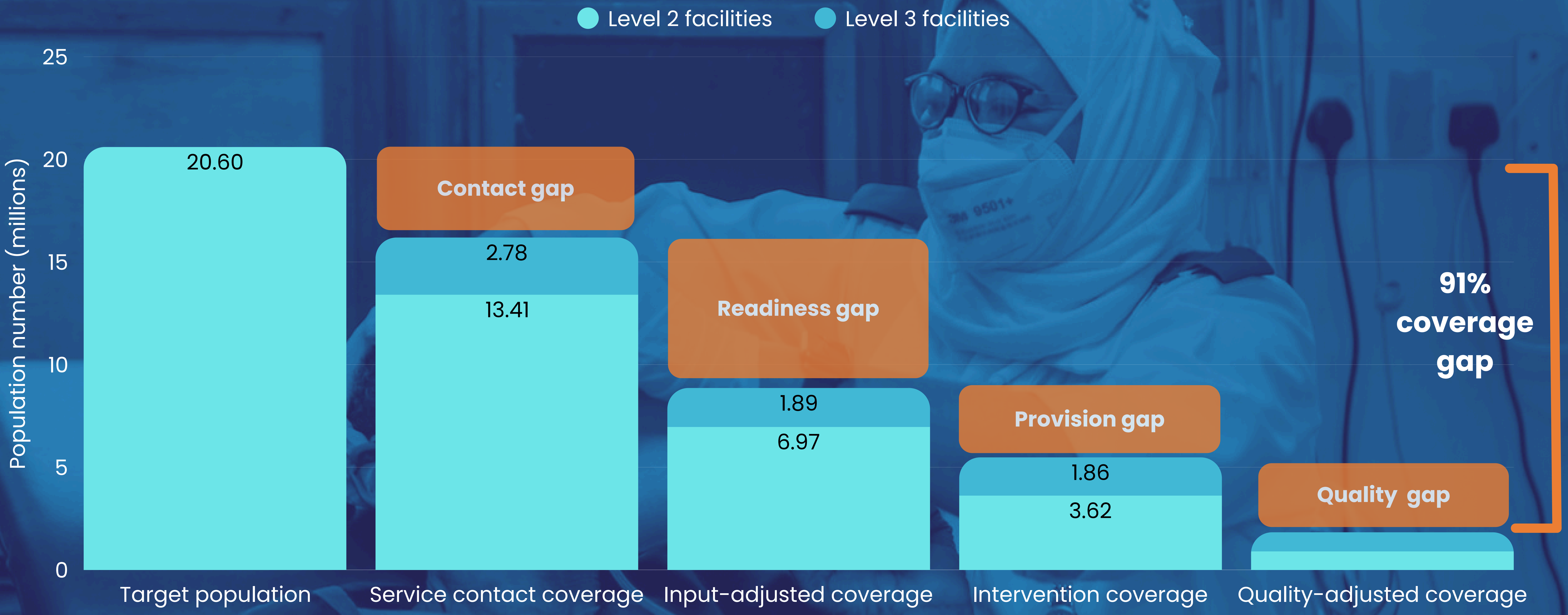
No regional breakdown for surgical or chronic oxygen needs due to lack of data



THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen coverage gaps

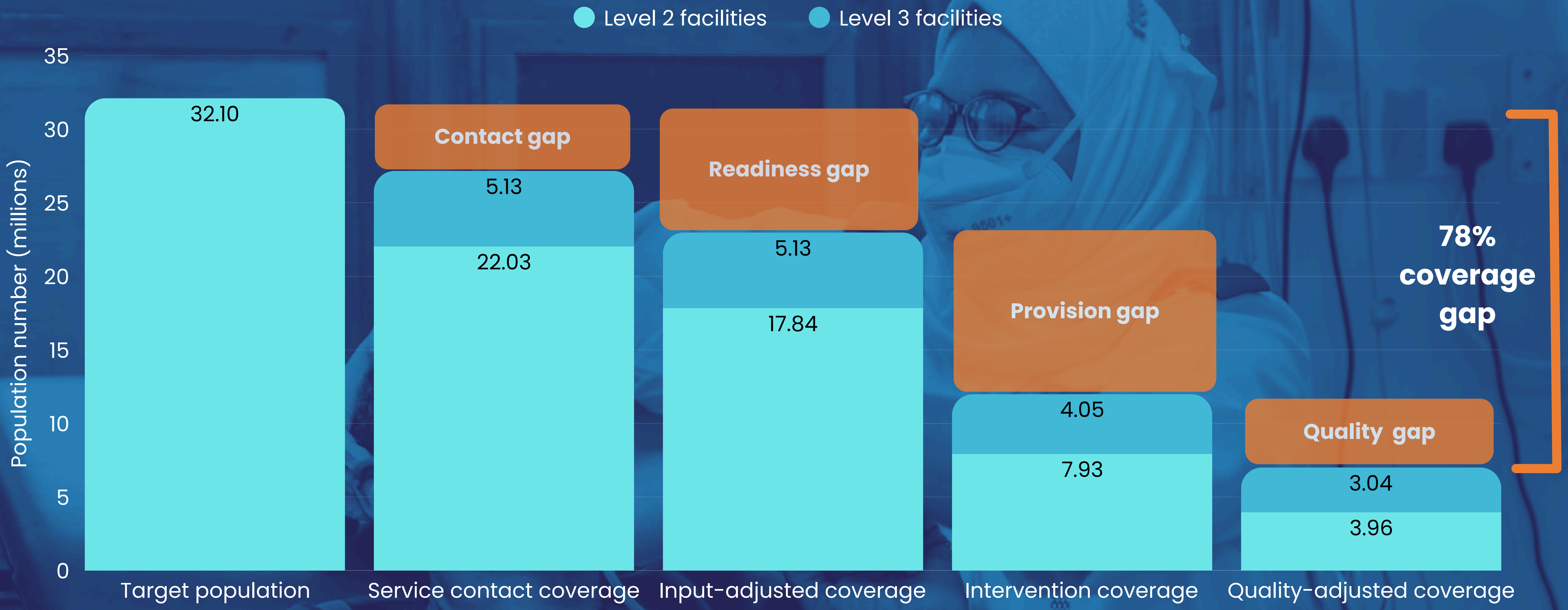
Why the coverage gap for acute needs in Sub-Saharan Africa?



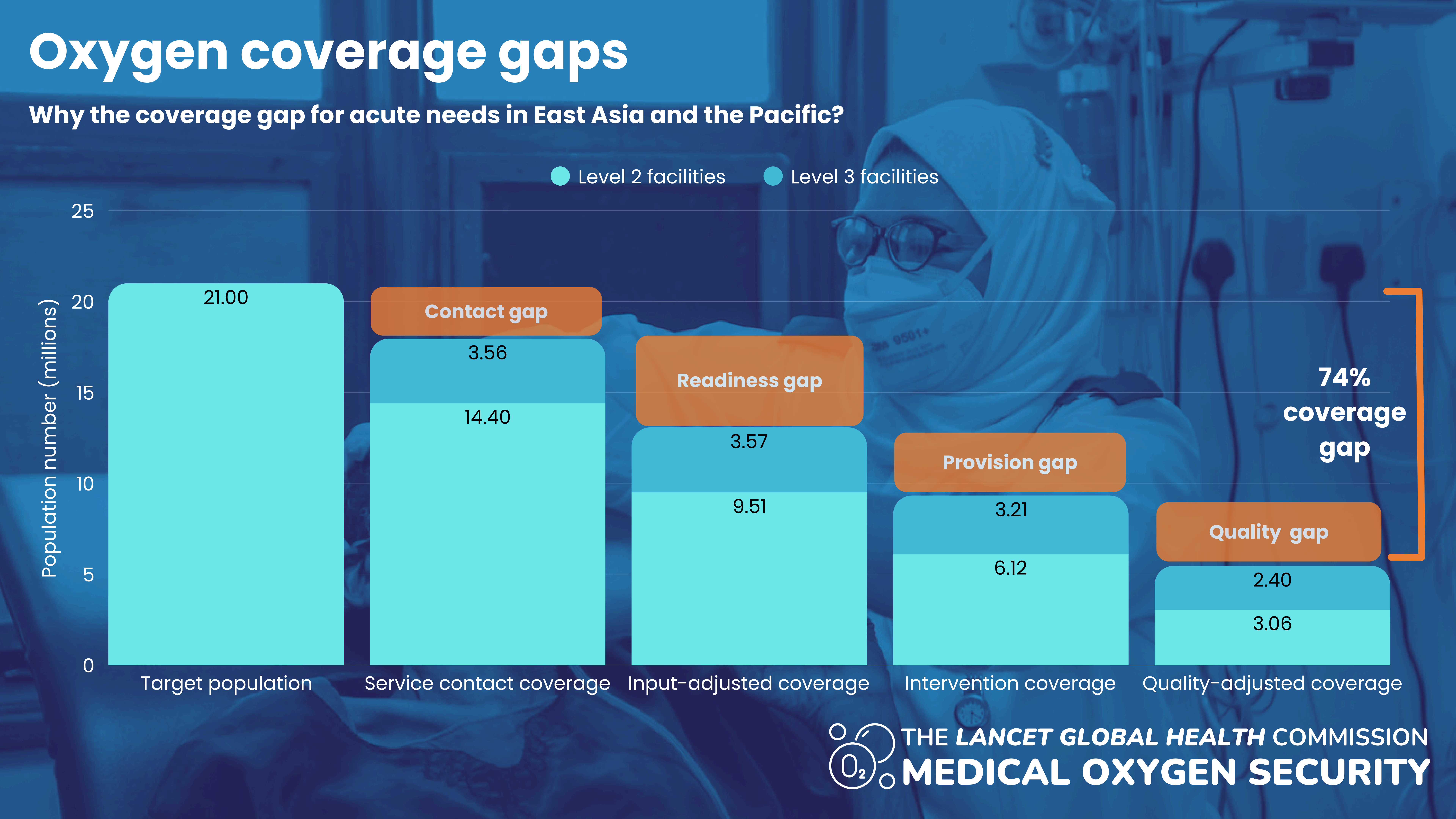
THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen coverage gaps

Why the coverage gap for acute needs in South Asia?



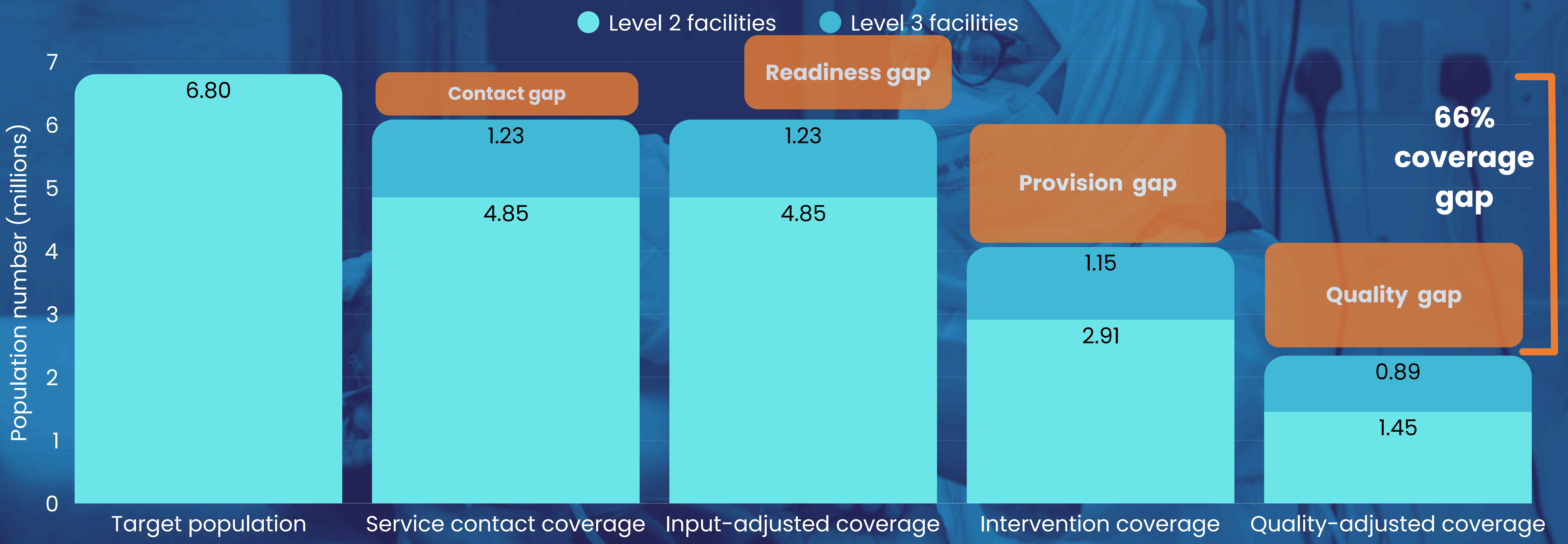
THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY



Oxygen coverage gaps
Why the coverage gap for acute needs in East Asia and the Pacific?
Level 2 facilities
Level 3 facilities
Population number (millions)
25
20
15
10
5
0
21.00
Contact gap
3.56
14.40
Readiness gap
3.57
9.51
Provision gap
3.21
6.12
Quality gap
2.40
3.06
74% coverage gap
Target population
Service contact coverage
Input-adjusted coverage
Intervention coverage
Quality-adjusted coverage
THE LANCET GLOBAL HEALTH COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen coverage gaps

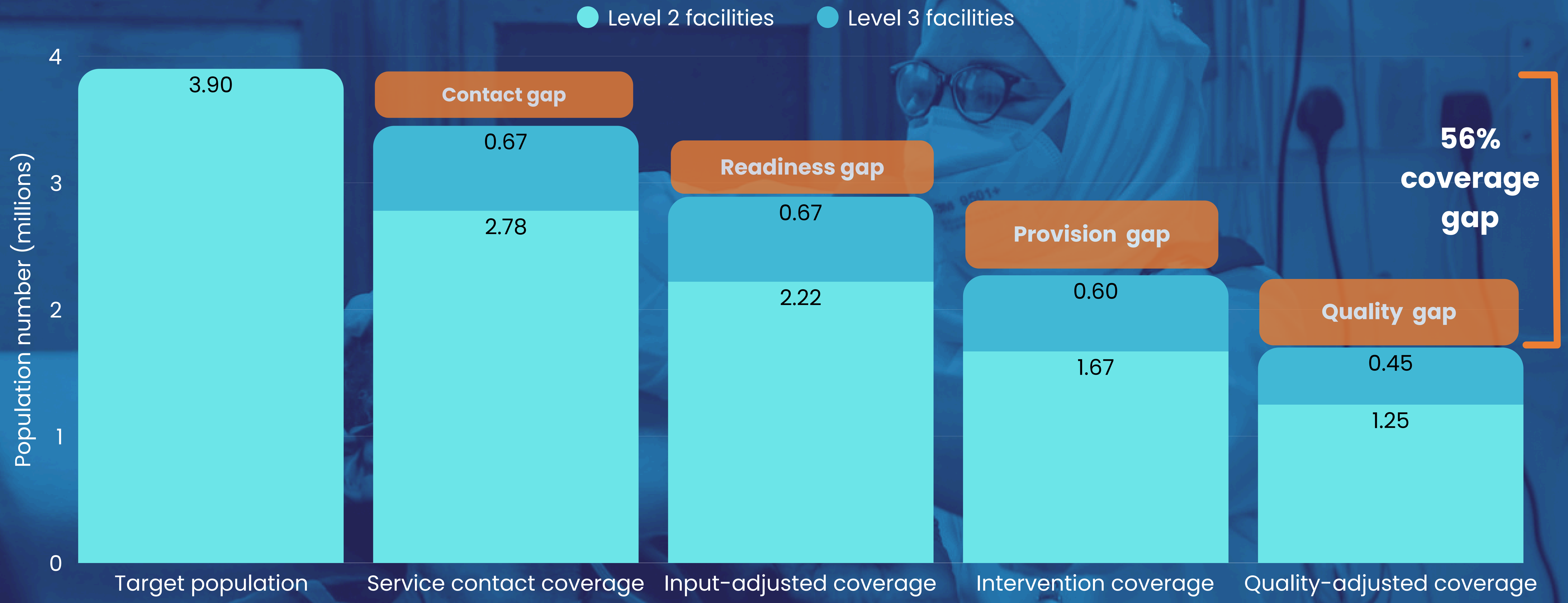
Why the coverage gap for acute needs in Latin America and the Caribbean?



THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen coverage gaps

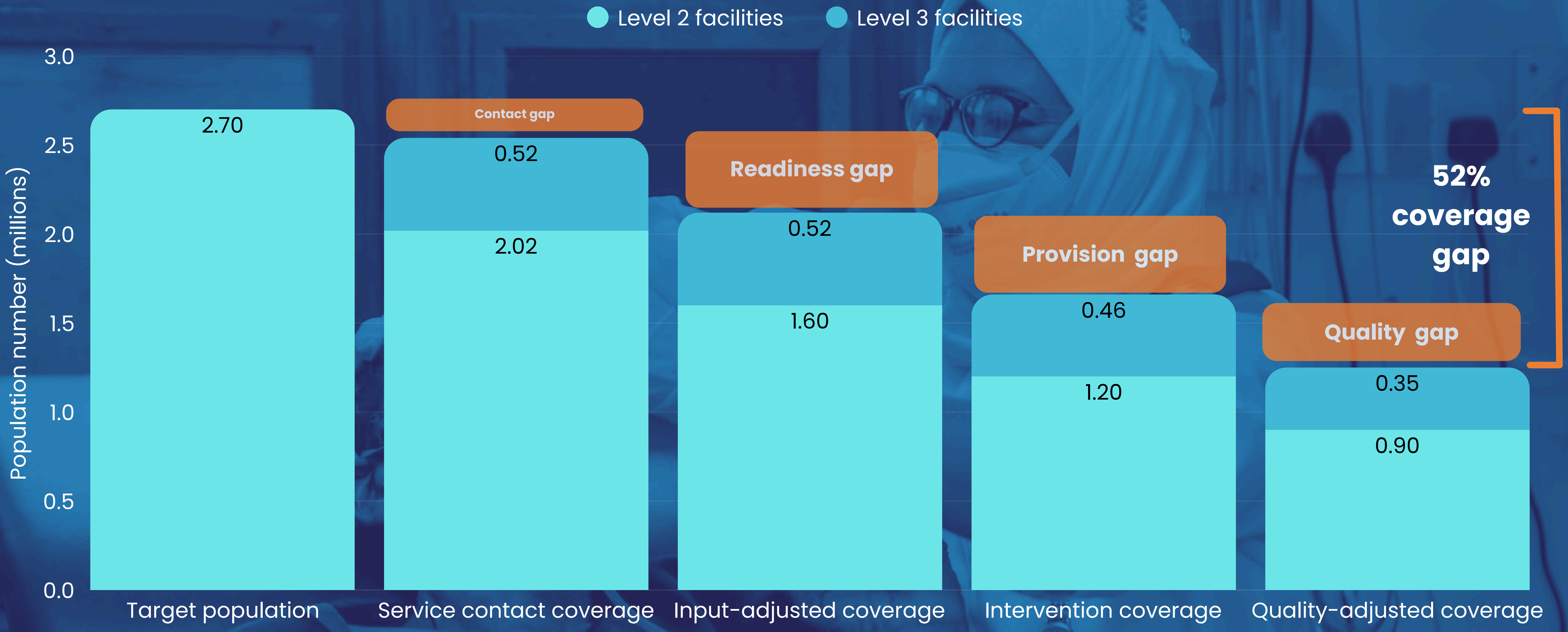
Why the coverage gap for acute needs in Middle East and North Africa?



THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen coverage gaps

Why the coverage gap for acute needs in Eastern Europe and Central Asia?



THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen coverage gaps

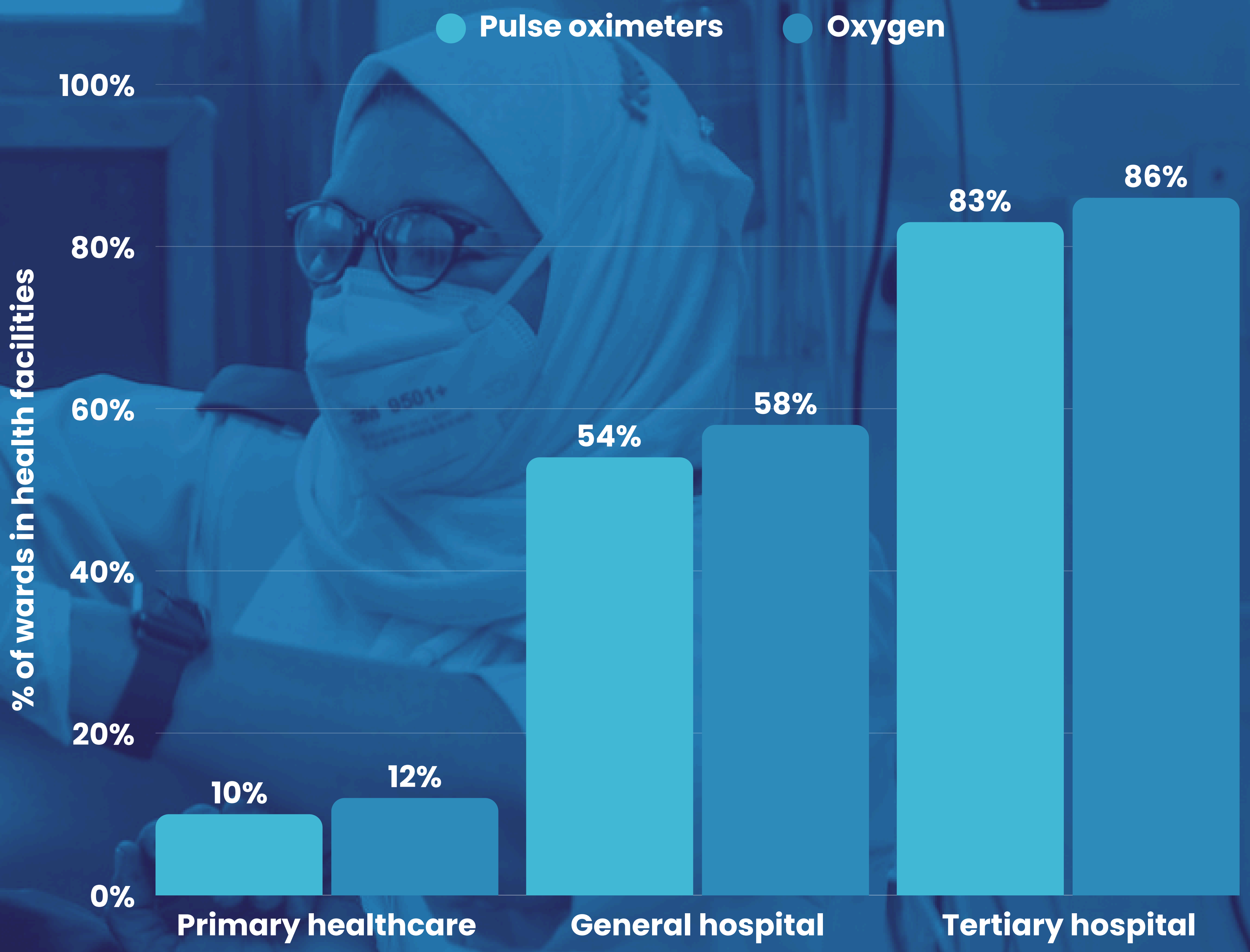
Health facility inequities in LMICs

Pulse oximeters and oxygen are available in:

- 10% and 12% of primary health facilities
- 54% and 8% of general hospitals
- 83% and 86% of tertiary hospitals

Pulse oximetry and oxygen access is:

- three times lower in rural vs urban health facilities
- three times lower in public vs private health facilities



THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen coverage gaps

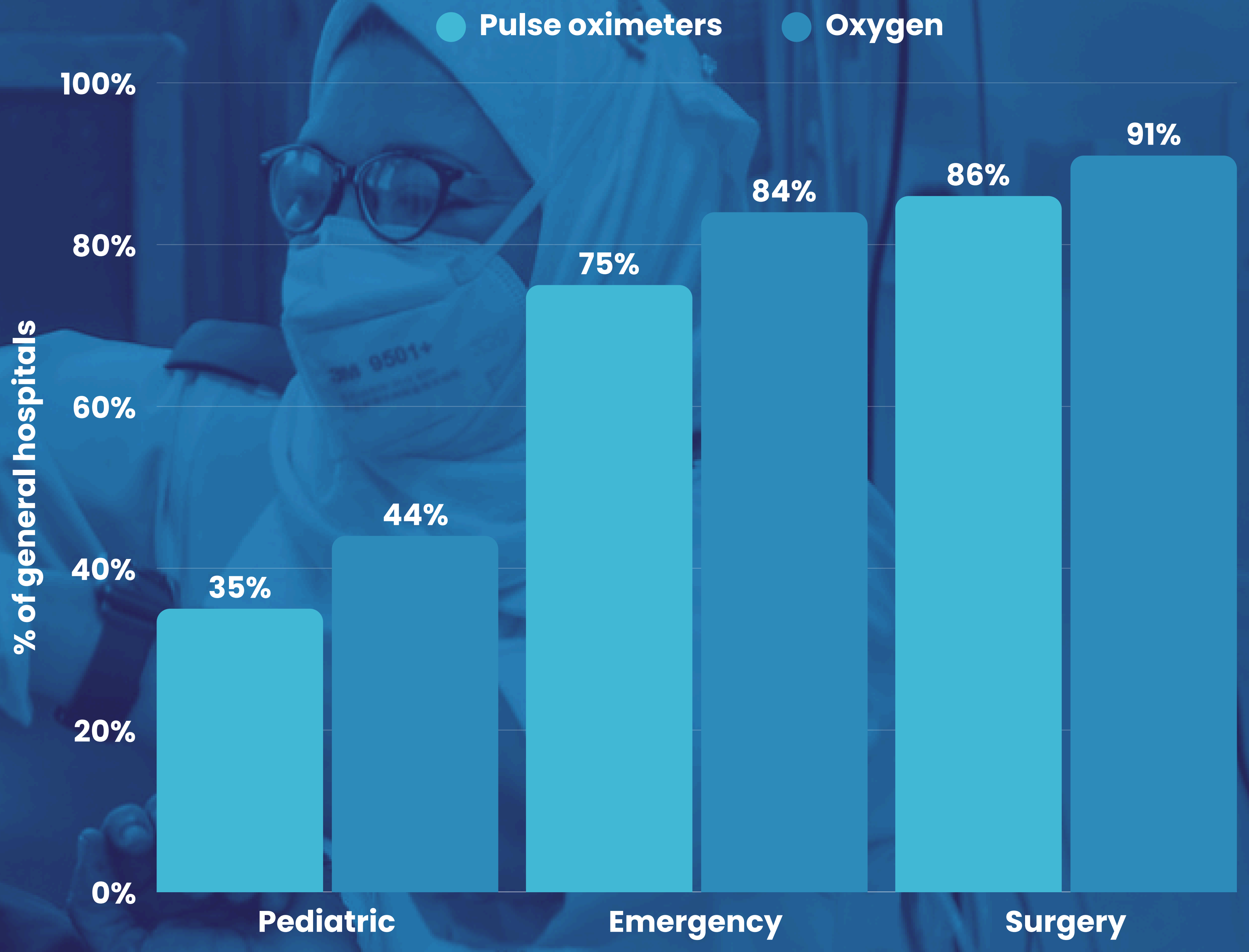
Ward inequities in LMIC health facilities

Pulse oximeters and oxygen are available in:

- 35% and 44% of pediatric wards
- 75% and 84% of emergency departments
- 86% and 91% of surgical wards

The greatest inequities in pulse oximetry and oxygen service delivery are for people—particularly children—attending small health facilities in rural areas, especially in sub-Saharan Africa and south Asia.

Lancet Global Health Oxygen Commission



THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen coverage gaps

What do patients think?

Community perceptions can influence acceptance and adherence to oxygen

- Fears of oxygen are can delay seeking care
- Seeing oxygen working can improve attitudes

High costs are a major barrier to oxygen access

At that time [2021], oxygen cylinders cost about 20,000 taka [US$180] each and you had to refill every 2–3 hours. It is almost impossible for patients who are not highly paid to afford medical oxygen.

Family of a patient with COVID-19, Bangladesh

Photo: ALIMA

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen cost

There should be no question as to whether investment in oxygen-system strengthening is value for money. Rather, the focus should be on how much funding is needed and how this money would be most effectively spent

Costing the oxygen coverage gap

How much will it cost?

US$6.8 billion a year is needed to close the coverage gap and US$34 billion from 2025-2030 (see Figure 6)

- South Asia: US$2·6 billion
- East Asia & Pacific: US$1·8 billion
- Sub-Saharan Africa: US$1·7 billion
- Latin America & Caribbean: US$436 million
- Middle East & North Africa: US$212 million
- Europe & Central Asia: US$148 million

A COVID patient used about four cylinders per day so we ran out quickly and asked the health ministry to send more, but they didn't have enough money.

Doctor, Sierra Leone

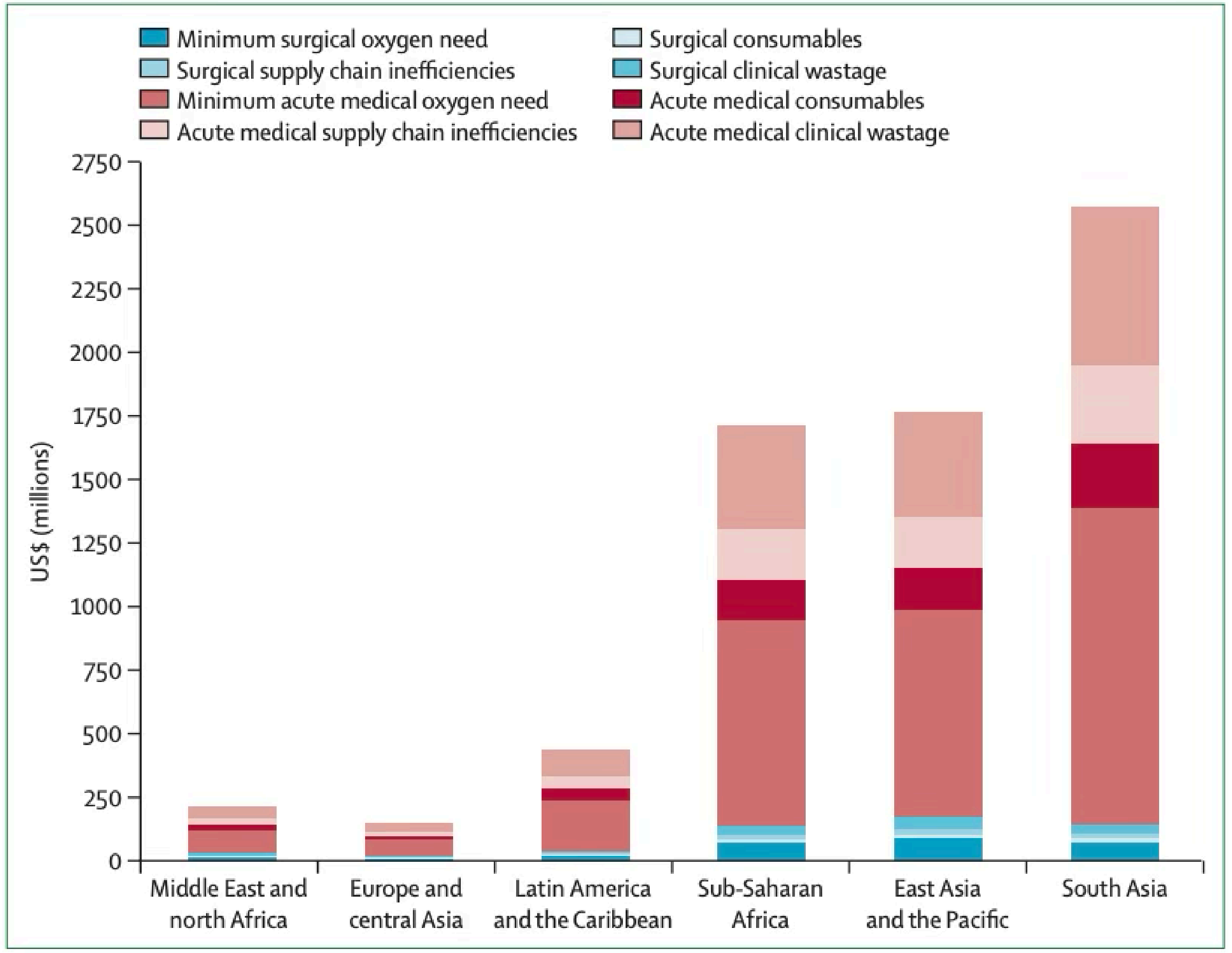


Figure 4: Annual cost to close the acute medical and surgical oxygen gaps in low-income and middle-income countries

The minimum cost of the medical and surgical oxygen need is the cost to fill the oxygen coverage gap, based on recommended treatment. We inflated this cost to reflect actual practice and included inefficiencies in the system, clinical wastage, and additional consumables in our estimates (appendix 1 p 78). Supply chain inefficiencies refer to leakages in oxygen delivery systems and losses during production, distribution, and storage. Clinical wastage is the use of higher flow rates for longer periods than recommended, and treatment of patients without a clinical need for oxygen. Consumables includes the cost of pulse oximetry, nasal cannulas, masks, and staff time.

92% of cost gap is acute medical

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Costing the oxygen coverage gap

How much will it cost?

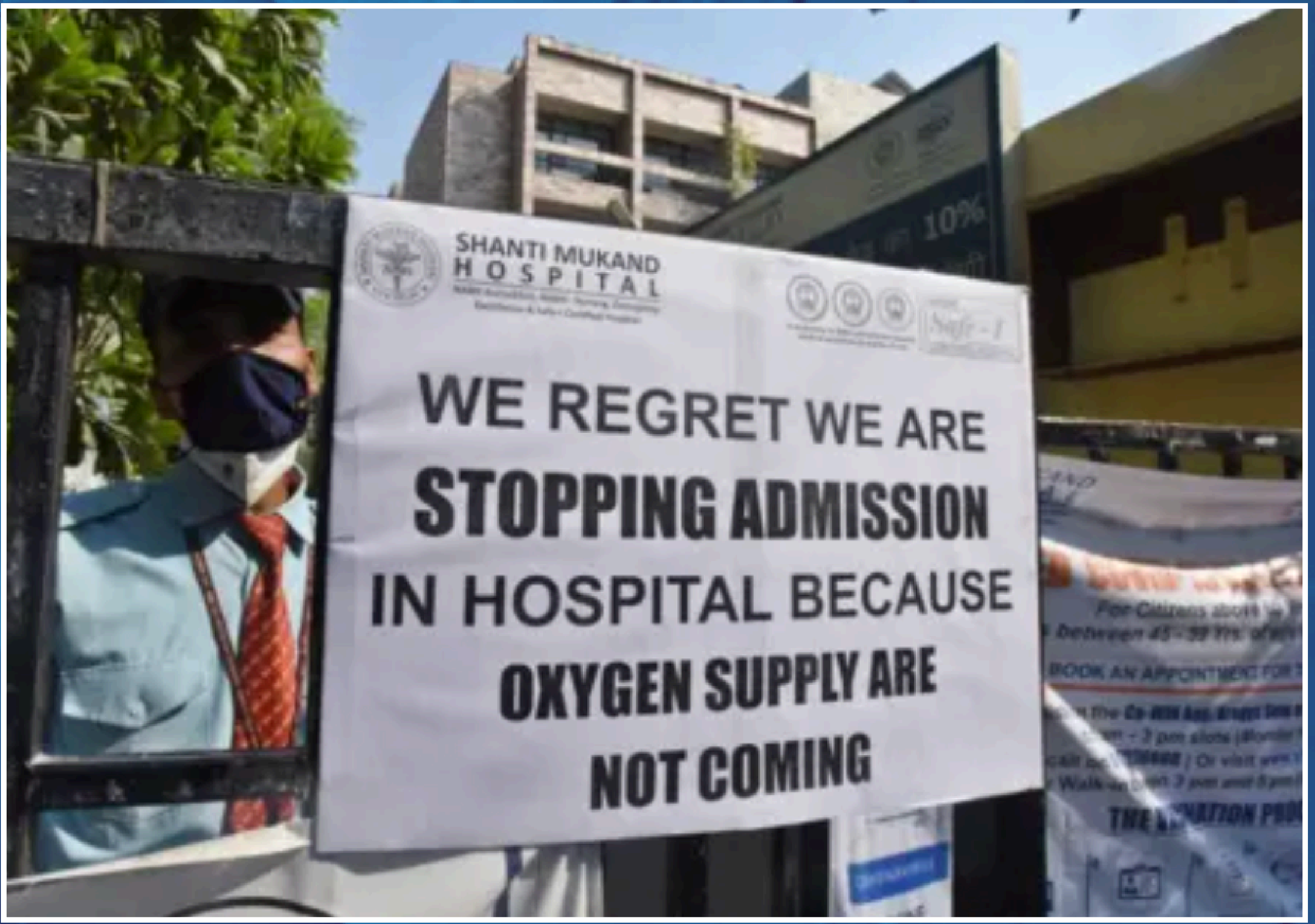
Emergencies

- COVID-19 required an additional US$6.8 billion to meet the increased oxygen need

Long-term oxygen therapy

- The cost to meet the long-term oxygen therapy need for COPD is US$3-US$10 billion a year. Limited data on long-term oxygen costs from LMICs

- Limited power supply will exacerbate inequities in home oxygen access – 675 million people did not have access to power at home in 2021



Hospital in Delhi, India, April 2021

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Costing the oxygen coverage gap

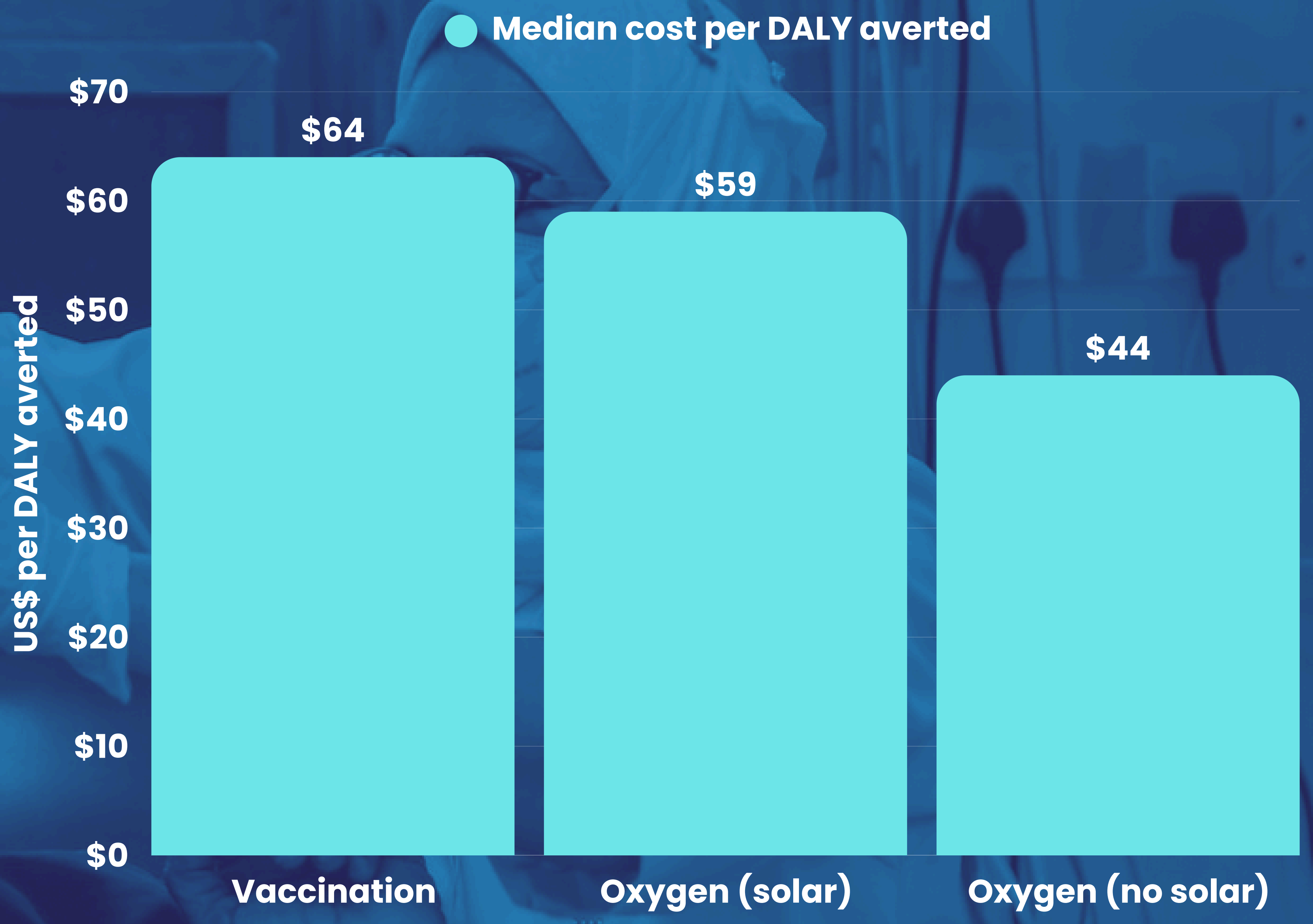
How much will it cost?

Highly cost-effective:

- US$44-59 per DALY averted (based on child pneumonia)
- Simlar to the most cost-effective child survival interventions (e.g, vaccination)

Each dollar invested could deliver estimated returns of US$21, and additional funding can cost approximately US$168 per disability-adjusted life year (DALY) averted, and as little as US$23 in countries with very high burdens.

Global Oxygen Strategic Framework and Investment Case 2025-30, 2024



THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Costing the oxygen coverage gap

How much will it cost?

Prevention of oxygen need in LMICs should be an urgent public health priority and will reduce future costs

Acute and surgical

- Increased vaccination (especially childhood pneumonia)
- Better nutrition
- Safer roads

Long-term

- Smoking reduction and cessation
- Air quality improvements (household and outdoor)
- Early diagnosis of COPD
- Increased access to inhaled medicines

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen solutions

The Commission's solutions address five areas - pulse oximetry; resilient oxygen systems; management of national oxygen systems; strengthening markets, regulations, and standards; and robust monitoring and evaluation

Oxygen solutions: pulse oximetry at all levels of care

SpO2 is a vital sign

Pulse oximetry is the gateway to safe and appropriate use of medical oxygen

- Hypoxaemia is an important danger sign
- Low SpO2 should prompt re-assessment, referral or follow-up

Implementation of pulse oximetry in primary care settings is feasible

- Introduction needs to consider wider service provision capacities
- Implementation needs to be supported by a functional referral system

Photo: Unitaid

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen solutions: pulse oximetry at all levels of care

Pulse oximetry is key to maximising the cost-efficiency of oxygen systems

Integrate pulse oximetry into all relevant clinical guidelines and training

- Missing from key guidelines (e.g., malaria, HIV/AID, TB) and absent from primary care guidelines
- Pre-service and in-service clinical training needed
- Practice-based, spaced and supported with job aides
- Supervision and mentorship are critical
- Motivation is lost when healthcare workers cannot treat hypoxaemic patients with oxygen therapy

“

Our modelling suggests that introduction of routine pulse oximetry across the health system could quintuple the net health benefit of oxygen implementation scenarios.

Thanzi la Onse Model

Oxygen solutions: building resilient oxygen systems

Oxygen systems are not a one-size-fits all solution

- Systems need to fit the context - including essential infrastructure and biomedical support
- Mixed sources of oxygen should be embraced
- Back-up oxygen sources are essential
- Affordable, uninterrupted and clean power
- Local energy environment needs to be planned for
- Equip devices with surge and voltage fluctuation protection
- Solar solutions should consider the needs of the whole facility
- New technologies should prioritize energy efficiency

Photo: The Global Fund

When the power went off, patients on the concentrators had to wait for the generator to kick in. Sometimes it took five minutes, and we had patients who died in that gap of time.

Doctor, Sierra Leone

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen solutions: building resilient oxygen systems

Oxygen system design must consider the total cost of ownership

Operational costs account for 50-90% of the total cost of ownership (see Figure 10)

- Distribution costs most important for cylinders
- Energy costs most important for PSA and concentrators
- Low-cost pulse oximeters can have higher total cost of ownership if they require frequent replacement

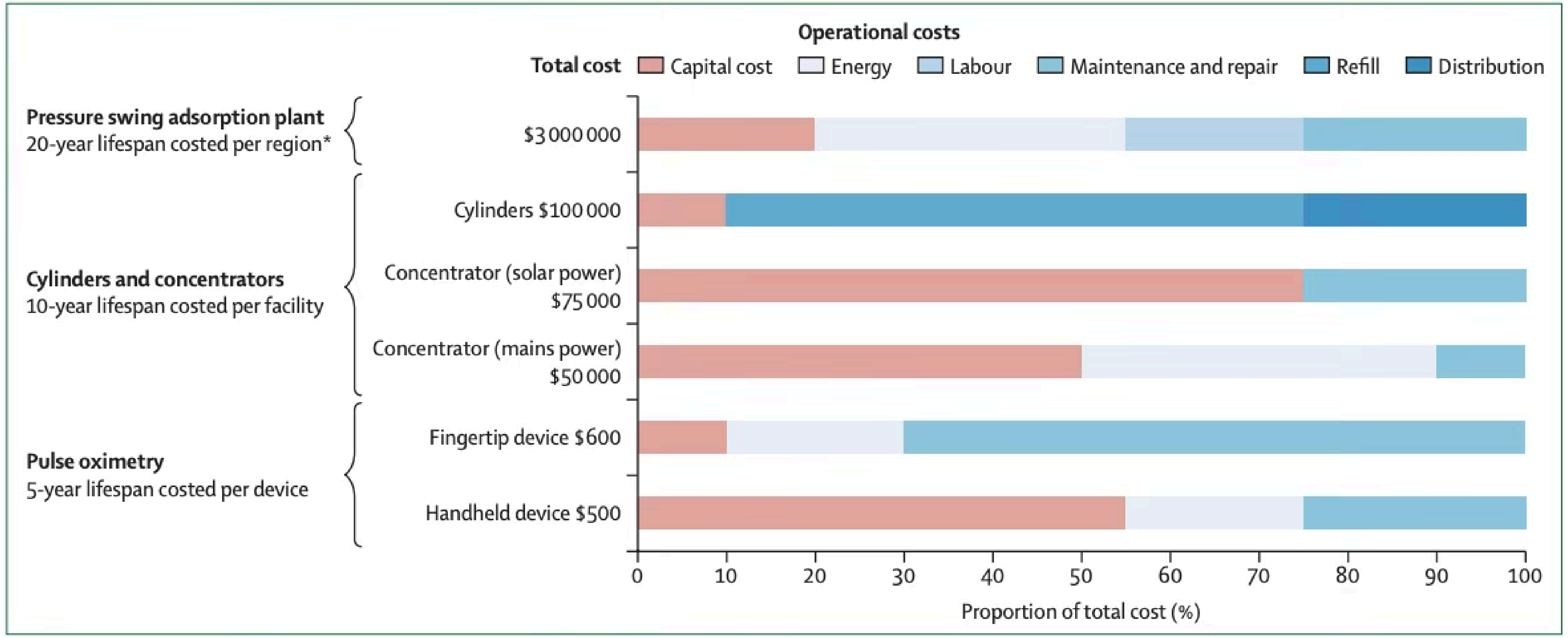


Figure 10: **Capital and operation costs of different oxygen system components**
Costs are an estimated total cost of ownership. The breakdown of cost categories (in US$) is based on data from publications[83,230–232] and Open Oximetry related to projects in six countries (Nigeria, Papua New Guinea, The Gambia, Kenya, Rwanda, and Ethiopia), and is intended to support budget planning. The balance between categories will vary by setting, and this figure should not be used as a cost-comparison tool. *Based on regional hub-and-spoke models.

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen solutions: building resilient oxygen systems

Biomedical engineers are vital members of the health workforce but investment is needed to strengthen capacity

- Skills and density need to align with the needs of the health system
- New target of >0.4 per 10,000 which should be reported in the WHO Global Health Workforce database
- Must be included in oxygen system planning

Biomedical engineers are a source of innovation

We prayed that this one concentrator that we all bandaged up by plaster - we basically Macgyvered it - would keep two patients alive. Human ingenuity during challenging times is amazing and both patients lasted the whole weekend.

Doctor, Ethiopia

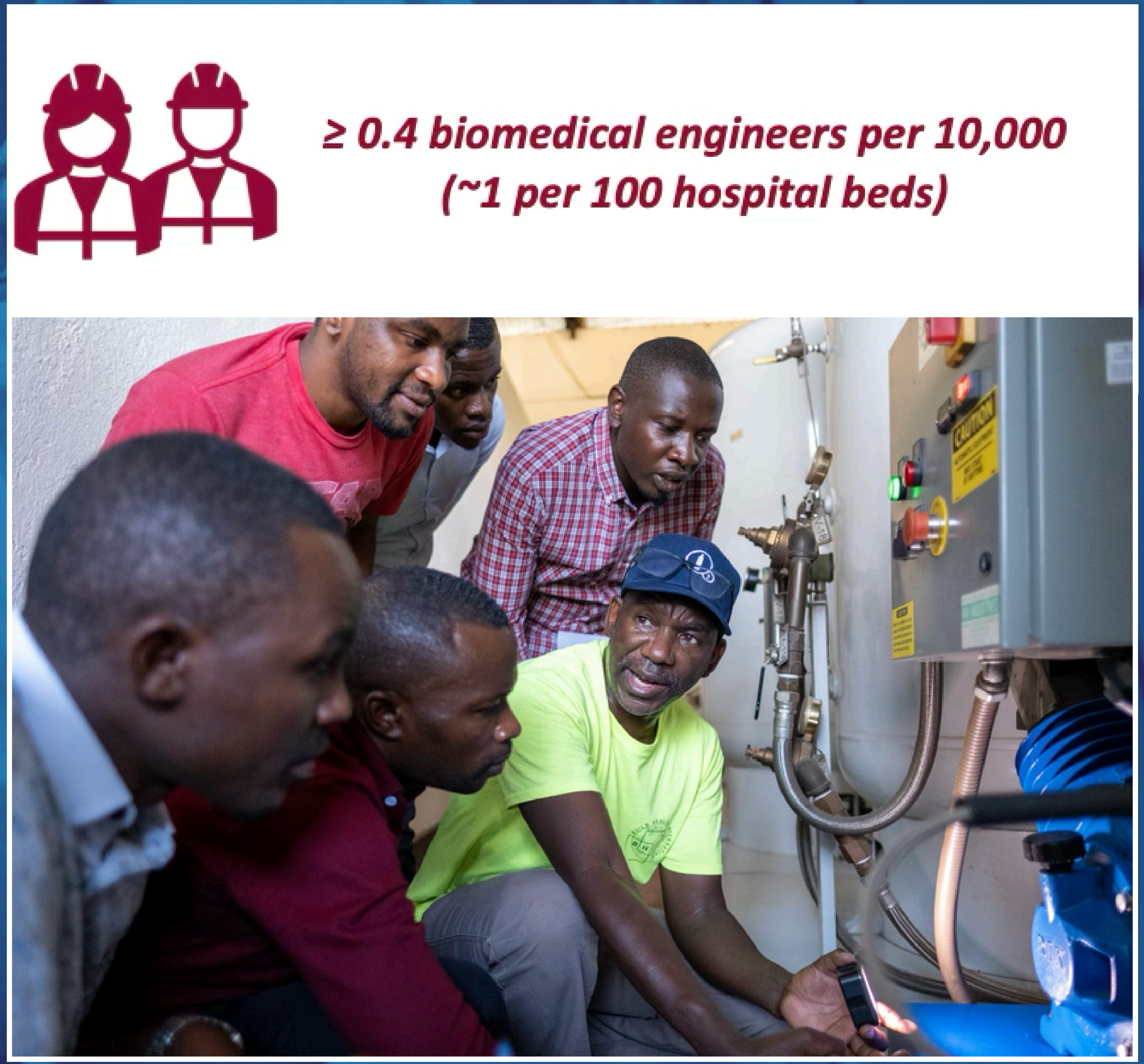


Photo: Build Health International

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen solutions: coordinated management

Coordination and planning across multiple stakeholders is needed

National Oxygen Plans/Roadmaps are powerful tools for coordination, advocacy, and fundraising

- Only 27 countries have published a plan
- M&E is the weakest domain in existing plans
- Oxygen is largely missing from pandemic preparedness and emergency planning

Coordination must connect stakeholder groups horizontally, with a clear point of contact

- Multiple government ministries are involved in the management of oxygen systems (see Figure 11)
- “Oxygen Desks” (Nigeria) are an example of Federal and State coordination

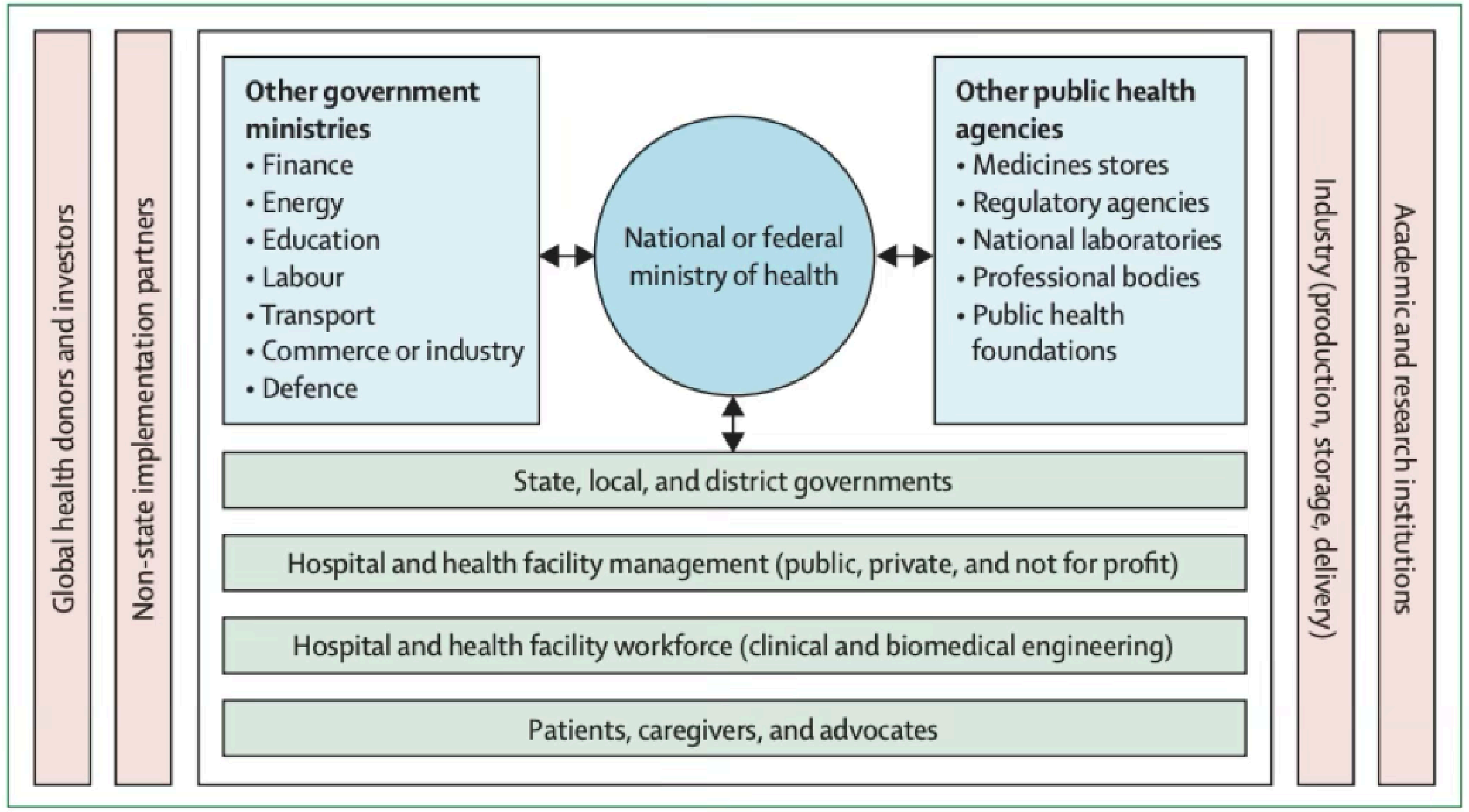


Figure 11: **Key stakeholders in a national medical oxygen system**
Adapted from Mirza et al (2023).[266]

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen solutions: coordinated management

International oxygen aid must align with needs, gaps, and capacity to implement

Over US$1 billion was donated for oxygen supplies during COVID-19 but it was not well targeted to highest-need regions (see Table 5)

- Funds should be targeted to countries with greatest needs and largest gaps
- Donors must coordinate to minimize duplication and maximise efficiencies
- Operational costs of equipment must be included (e.g., <1% of COVID-19 oxygen aid was for operational costs)

	Proportion of global coverage gap for acute and surgical oxygen need (%)	Proportion of global COVID-19 oxygen need (%)	Proportion of global COVID-19-related deaths (%)*	Value of oxygen aid (millions of US$), 2021–23†	Proportion of total global oxygen aid (%)
East Asia and Pacific	26%	9%	9%	59·4	14%
Europe and central Asia	4%	16%	22%	48·3	12%
Latin America and the Caribbean	7%	11%	17%	16·8	4%
Middle East and north Africa	3%	7%	3%	46·8	11%
North America	0	4%	7%	<0·1	0
South Asia	37%	29%	29%	41·9	10%
Sub-Saharan Africa	23%	24%	14%	197·6	48%

Because of rounding, percentages do not always sum to 100%. *Global Burden of Disease data. †WHO COVID-19 supply chain dashboard data (unpublished).

Table 5: COVID-19 oxygen need, mortality, and international funding, by World Bank region, 2021

While setting up PSA plants, the Ministry of Health did not include maintenance budgets for these plants. When the plants break down, hospitals incur the cost of bringing in a maintenance engineer but there is often no budget line.

Ministry of Health Official, Uganda

Oxygen solutions: regulations and markets

Medical oxygen industry, like the pharmaceutical industry, is a critical player in global public health

- Companies should have access to medical oxygen targets, teams, and initiatives
- Report progress in annual reports to shareholders
- Governments need to foster fair market conditions to ensure competition and market entry
- Open tenders are critical to address current oligopolies and high prices

Photo: One Health Trust

We have very few companies that make oxygen and most hospitals do not have the capacity to manufacture their own, so we have to rely on company monopolies, and this created the situation that we found ourselves in.

Son of deceased COVID-19 patient, Kenya

Oxygen solutions: regulations and markets

National medical oxygen definitions should mirror the International Pharmacopoeia

- include cryogenically-distilled liquid oxygen (oxygen 99.5%)
- PSA/VSA-generated oxygen (oxygen 93%)
- both safe for patient use

This will enable competition between the suppliers of liquid oxygen and on-site PSA/VSA plants

It was a political and economic issue because, by raising the level of oxygen purity it was directed to two companies that were the only ones [that would] meet that requirement… it was like giving the way only to the two of them

Peru Case Study

Working document QAS/20.867/Rev6
May 2022
For publication in the 11th Edition of Ph.Int.

World Health Organization

[Note from the Secretariat. The monograph on Medicinal Oxygen was adopted at the 56th meeting of the WHO Expert Committee on Specifications for Pharmaceutical Preparations for publication in the 11th Edition of The International Pharmacopoeia. *In the interim, the monograph is made available on the WHO website. The text may be subject to appropriate editorial modifications and will replace the monograph on Oxygen.]*

MEDICINAL OXYGEN

(OXYGENIUM MEDICINALIS)

Molecular formula. O_2

Relative molecular mass. 32.00

Chemical name. Oxygen; CAS Reg. No. 7782-44-7.

Description. A colourless gas.

Category. Gas for inhalation.

Additional information. Oxygen is mentioned in the current *WHO Model list of essential medicines* (EML) and in the *EML for Children*.

Depending on the clinical medicinal necessity and in accordance with clinical guidelines, Medicinal Oxygen is used either (1) in the undiluted form, (2) as mixtures of Oxygen 93%, Oxygen 99.5% or other oxygen products, or (3) in the undiluted form or as mixtures in combination with ambient or compressed air of a suitable quality or other medicines.

WHO International Pharmacopoeia

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

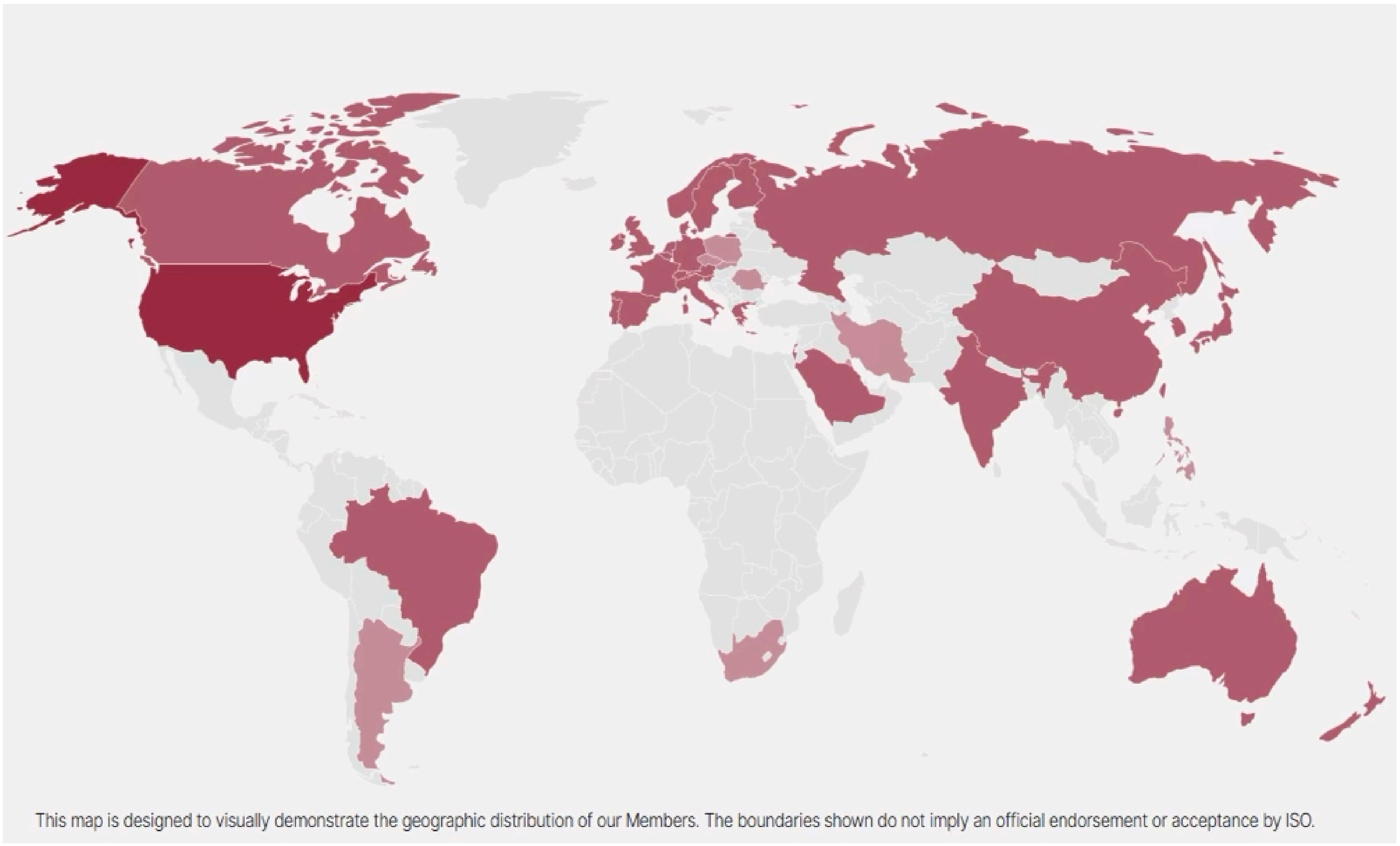
Oxygen solutions: regulations and markets

Regulatory bodies must ensure fit for purpose oxygen equipment and governance

- High-quality pulse oximeters with quality performance across skin tones
- Harmonized standards for oxygen cylinder connections
- Increased interoperability
- Reduced "lock-in" to specific providers
- Prevent equipment graveyards

Include LMICs in standards bodies

- Just 6 of 31 representatives on ISO Anaesthetic and Respiratory Equipment and Supplies Technical Committee 121 are from LMICS
- Standards are not sensitive to LMIC contexts



Geographic representation on ISO Technical Committee 121

Oxygen solutions: data for impact

Accurate and timely data is essential for effective evidence-informed decision making

Current indicators for measuring medical oxygen coverage are inadequate

- Rely too heavily on equipment availability
- Inadequately assess patient-level access, affordability or quality

Commission proposes two new tools:

- 10 Oxygen Coverage Indicators (see Table 7)
- Access to Medical Oxygen Scorecard or ATMO$_2$S (see Figure 13)

	Definition	Target
Pulse oximetry coverage*	Proportion of patients presenting to hospital with acute illness or undergoing surgery whose SpO_2 is documented at triage or admission (or during non-emergency surgery)	>80%
Oxygen production and storage capacity*	Mean (and maximum) monthly production volume (in Nm^3) of medical oxygen, and storage capacity, of each production facility (air separation units for cryogenic production of liquid oxygen or pressure-swing or vacuum-swing adsorption oxygen plants)	Individualised country targets
Pulse oximeter and oxygen availability*	Number and proportion of acute ward areas in health facilities with a functional pulse oximeter and an oxygen supply sufficient to meet patient need in the past month	100%
Pulse oximetry and oxygen service accessibility	Proportion of the population who can access, within 2 h, a health facility that provides low-flow oxygen services, including pulse oximetry measurement and monitoring	100%
Hypoxaemia prevalence	Proportion of patients attending a health facility who have hypoxaemia (ie, SpO_2 <90%) at triage or admission	None (reflects magnitude of oxygen need)
Oxygen coverage	Proportion of patients with hypoxaemia (ie, SpO_2 <90%) at triage or admission to a health facility who receive oxygen therapy within 1 h	>80%
Hypoxaemia-related mortality	Proportion of patients attending a health facility who have hypoxaemia (ie, SpO_2 <90%) and die before discharge or within 30 days	Individualised country targets
Clinical workforce	Number of doctors, nurses, and midwives per 10 000 population	≥44·5 clinicians per 10 000 population[249]
Biomedical engineering workforce	Number of biomedical engineers (defined broadly as per WHO[244]) per 10 000 population	≥0·4 biomedical engineers per 10 000 population†
Protection against catastrophic health expenditure	Proportion of patients receiving medical oxygen whose out-of-pocket expenditure on oxygen services is greater than 1% of their total annual household expenditure or income	<5% of patients experience catastrophic health expenditure

These indicators are most useful when used and interpreted collectively, because no one indicator in isolation provides an adequate representation of oxygen-related service provision. All targets should be adapted to the local context and given a timeline. SpO_2=oxygen concentrations in peripheral blood. Nm^3=normal cubic metres. *Highest priority and most feasible indicators. †In the absence of accepted global targets for biomedical engineering workforce, we propose a new target (appendix 1 p 102).

Table 7: Core indicators for monitoring universal access to safe, affordable, high-quality pulse oximetry and medical oxygen services

Oxygen solutions: data for impact

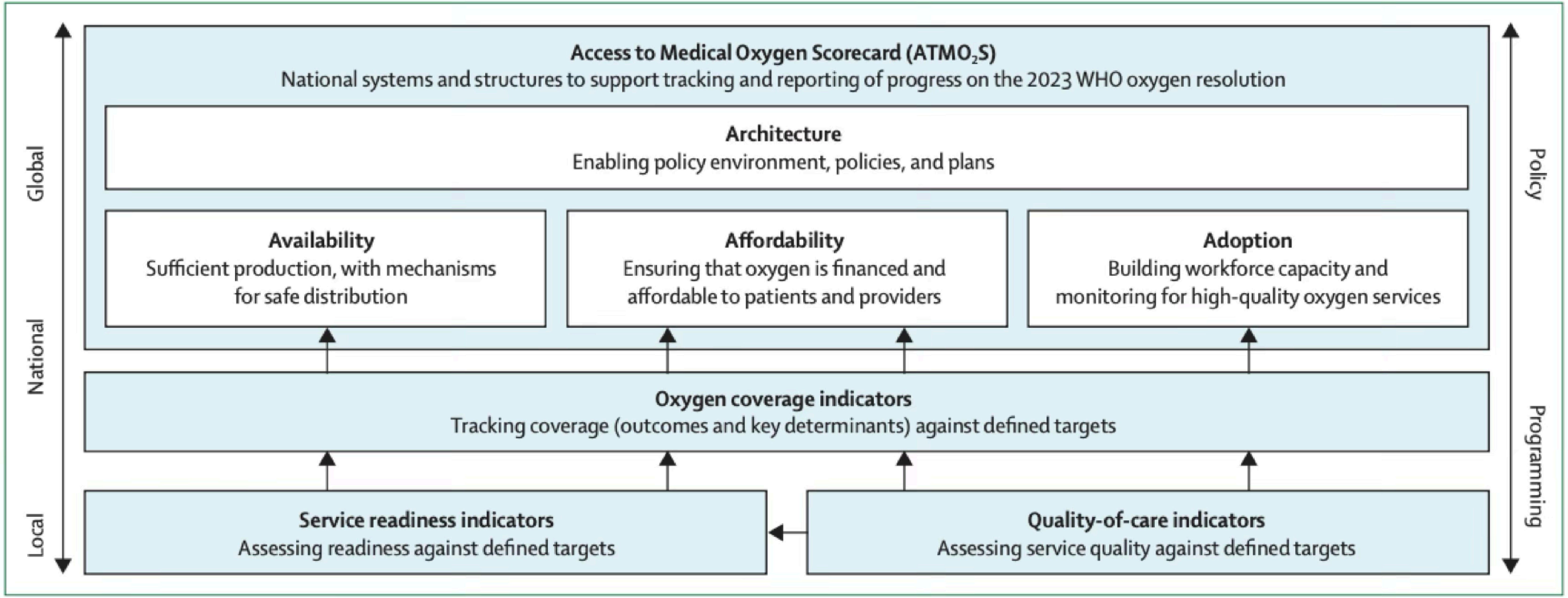


Figure 13: Proposed approach and indicators for a national medical oxygen monitoring framework

Oxygen solutions: the total picture

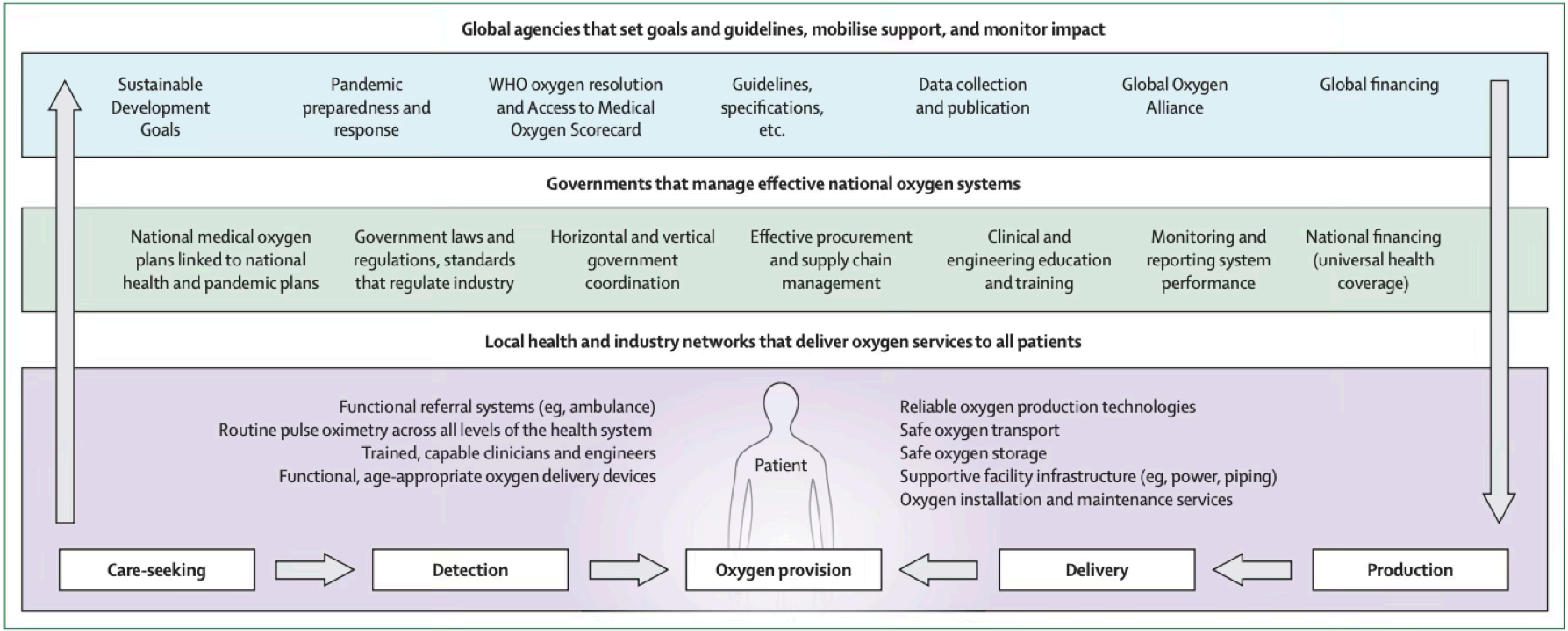


Figure 8: **Key features of a resilient national medical oxygen system**
The arrows depict inter-related efforts and the direction of patient and medical oxygen flows required to provide treatment to a patient in hospital.

Oxygen innovations

20 priority areas for investment in oxygen innovations

- Many of the examples cited originated in LMICs (see Table 4)

National governments, global health agencies, and donors must invest more in innovations

- High-impact products and services with the greatest promise of sustaining medical oxygen access cost-effectively
- Innovators and insitutions based in the countries with the widest gaps in oxygen access
- Potentially breakthrough solutions to the major barriers in access

	Examples
Pulse oximetry and oxygen use	
Improve accuracy of pulse oximeters	Open Oximetry: a free online platform that reports pulse oximetry performance based on independent studies
Improve clinical and biomedical oxygen-related training	The Oxygen Series: an extensive series of free, online training videos and resources in multiple languages for clinicians in LMICs from Stanford Medicine, Assist International, and Lifebox
Develop better, more affordable oxygen delivery devices	Polite CPAP: low-cost neonatal CPAP device designed and built in Nigeria to replace the commonly used improvised CPAP devices[254]*
Strengthen professional associations	African Women in Biomedical Engineering Alliance: the first professional association for women working as biomedical engineers and technicians across Africa, with the aim of strengthening skills, networks, and opportunities for leadership, and closing the wide gender gaps in the profession*
Oxygen supply systems	
Develop more robust oxygen concentrators	PulmO2: a 10 L per min oxygen concentrator designed to the specifications of UNICEFs target product profile
Reduce graveyards of broken equipment	OpenO2: an organisation of mobile biomedical engineers who repair broken oxygen concentrators and related devices for a fraction of the cost of purchasing new equipment*
Improve oxygen service management models	Airbank: a social business delivering oxygen directly to hospitals in Nigeria and Kenya as part of the Oxygen Hub (which provides entrepreneurs in Kenya, Ethiopia, and Nigeria with financing, equipment leasing, and management support)*
Develop more affordable methods of oxygen generation	Medical ceramic oxygen generator: a new technology for generating medical oxygen in harsh operating environments based on ceramic ion transport membrane technology
Improve access to spare parts	Centralised procurement mechanism for oxygen compressor spare parts: a mechanism that provides fast access to affordable spare parts for oxygen plants designed by PATH and partners
Introduce power-outage-proof oxygen technologies	FREO2 low-pressure oxygen system: this system includes a reserve that holds excess oxygen from a concentrator; if the power cuts out, this oxygen is automatically released, providing a supply that lasts 8–10 h
Reduce energy costs of oxygen plants	Africa Infrastructure Relief and Support: an initiative providing installation and maintenance of solar-powered oxygen plants and biomedical engineering training at three sites in west Africa
Coordination	
Strengthen national government leadership	National medical oxygen plans: government plans outlining how a country will ensure access to pulse oximetry and medical oxygen*
Improve oxygen data generation and management	India's national medical oxygen grid: an online platform for hospitals to manage medical oxygen supplies and for governments to minimise stockouts at local, regional, and national levels*
Raise awareness about oxygen as an essential medicine	World Oxygen Day: a global effort to rally the world to advocate for access to medical oxygen held annually on Oct 2
Connect public and private oxygen sectors	Oxygen Alliance: a collaboration of public and private sector stakeholders for the repair and maintenance of biomedical devices to ensure the delivery of high-quality health care*
Better coordinate management of national oxygen systems	Oxygen desks, Nigeria: dedicated officers, based in federal and state ministries of health, who coordinate medical oxygen activities horizontally across national stakeholders and vertically with subnational stakeholders*
Better coordinate global oxygen support to LMICs	Global Oxygen Alliance: an alliance of 20 global health agencies and donors providing oxygen support to LMICs
Oxygen markets and regulation	
Reduce anti-competition practices in the oxygen industry	*WHO Pharmacopoeia*: This standard defines both 99% and 93% oxygen as safe for medical use and enables the mixing of oxygen from both sources, reducing the risk that health facilities will be locked in to one supplier
Increase manufacturing and supply chain management in LMICs	Hewatele's east Africa liquid oxygen plant: the first fully African-owned liquid oxygen facility with finance from donor governments, development finance institutions, and philanthropists*
Increase corporate oxygen access responsibility	Aire Liquide Access Oxygen: a corporate programme that involves company oxygen access targets, regular reporting, and flagship programmes in several LMICs to increase access to medical oxygen

The use of brand names or any mention of specific commercial products or services is solely for educational purposes and does not imply endorsement by the *Lancet Global Health* Commission on medical oxygen security. LMICs=low-income and middle-income countries. CPAP=continuous positive airway pressure. *LMIC innovation.

Table 4: **Priority areas for medical oxygen-related innovation**

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY

Oxygen research priorities

Big opportunities

- address current knowledge gaps (see Panel 17)
- build a "learning health system"
- continually generate and translate learning into policy and practice

DESCRIPTION

- Hypoxaemia burden
- Long-term oxygen therapy needs
- National oxygen coverage gaps
- Oxygen cost drivers
- Extent of anti-competitive practices
- Oxygen demand reduction
- Physical and psychological effects of oxygen therapy...

DELIVERY

- Mixed-supply oxygen systems
- oxygen system management models
- medical oxygen sources cost-effectiveness
- oxygen conservation tools
- out-of-pocket cost reduction strategies
- oxygen delivery devices cost-effectiveness...

DEVELOPMENT

- oxygen need forecastig models
- oxygen data collection and integration tools
- humanitarian oxygen solutions
- AI-enabled oxygen monitoring tools
- next generation pulse oximeters...

Recommendations

The Commission makes 52 recommendations for governments, industry, global health actors, academics, and professional bodies to work towards by 2030 and recommend that an independent body assess progress in 2027, with the results made publicly available

Recommendations

Government

Donors

Industry

Global Health

Professions

Civil Society

Academic

Standards

PubMed.gov

ISO

Recommendations

Government

- Develop national medical oxygen plans
- Increase domestic spending
- Update clinical guidelines, medical lists, and policies
- Integrate oxygebn indicastiors
- Negotiate affordable and reliable oxygen congtracts with industry...

Industry

- Develop access to medical oxygen targets, teams, and initiatives
- Commit to greater price transparency
- Invest in innovations
- Design products to meet needs of emerging markets
- Increase LMIC manufacturing...

Recommendations

Global Health

- Include pulse oximetry and oxygen in all health and pandemic-related clinical guidelines, surveys, instruments, etc
- Support national governments to develop national oxygen plans
- Ensure 50% of future oxygen initiatives cover operational costs
- Increase access to oxyfenb data as global public good...

Donors

- Contribute to the Global Oxygen Alliance's $US4 billion fundraising target
- Support full replenishment of Global Fund
- Announce Pandemic Fund call for oxygen proposals
- Increase development bank financing
- Procure quality oxygen devices
- Increase funding for maintenance...

Recommendations

Civil Society

- Integrate medical oxygen advocacy into civil society health initiatives
- Hold governments accountable
- Support deveopment of national oxygen roadmaps
- Establish patient advocacy groups
- Strengthen civil society voice in Global Oxygen Alliance
- Increase the impact of World Oxygen Day

Academic

PubMed.gov

- Increase research in 20 priority areas (Panel 17)
- Support implementation science, health systems, and health economics researchers
- Champion the use of the Commission's core oxuen coverage indiactors
- Identify gaps in workforce capacity
- Include oxygen in clinical and biomedical curricula

Recommendations

Standards

- Review all standards relating to medical oxygen provision for alignment with WHO Oxygen Resolution
- Reduce fragmentation in standards across regions
- Ensure than at least 50% participating members of ISO TC 121 are from LMICs

Professions

- Formalize national biomedical engineering professional assocations in each country
- Fortify regional professional associations
- Ensure clinical professional societies support workforce development to strengthen access to pulse oximetry and oxygen...


"
With this Commission, and the recommendations we put forward, national medical oxygen systems can be at the forefront of efforts to create the future we want by ensuring the long-term health and sustainability of people and the planet
THE LANCET GLOBAL HEALTH COMMISSION
MEDICAL OXYGEN SECURITY

Find out more...

The full Commission package is available at www.stoppneumonia/lancetoxygencommission.org:

- Report with Comments
- Media Statement
- Policy Brief (English, French, Spanish, Arabic, Chinese, and Russian)
- Spotlight Brief: Access to Medical Oxygen Scorecard (ATMO_2S)
- Spotlight Brief: Patient and Caregiver Testimonies
- Spotlight Brief: 10 Oxygen Coverage Indicators
- Spotlight Brief: 20 Priority Areas for Oxygen Innovation
- Country Case Studies (Bangladesh, India, Malawi, Nigeria, Sweden, Uganda)

THE *LANCET GLOBAL HEALTH* COMMISSION
MEDICAL OXYGEN SECURITY