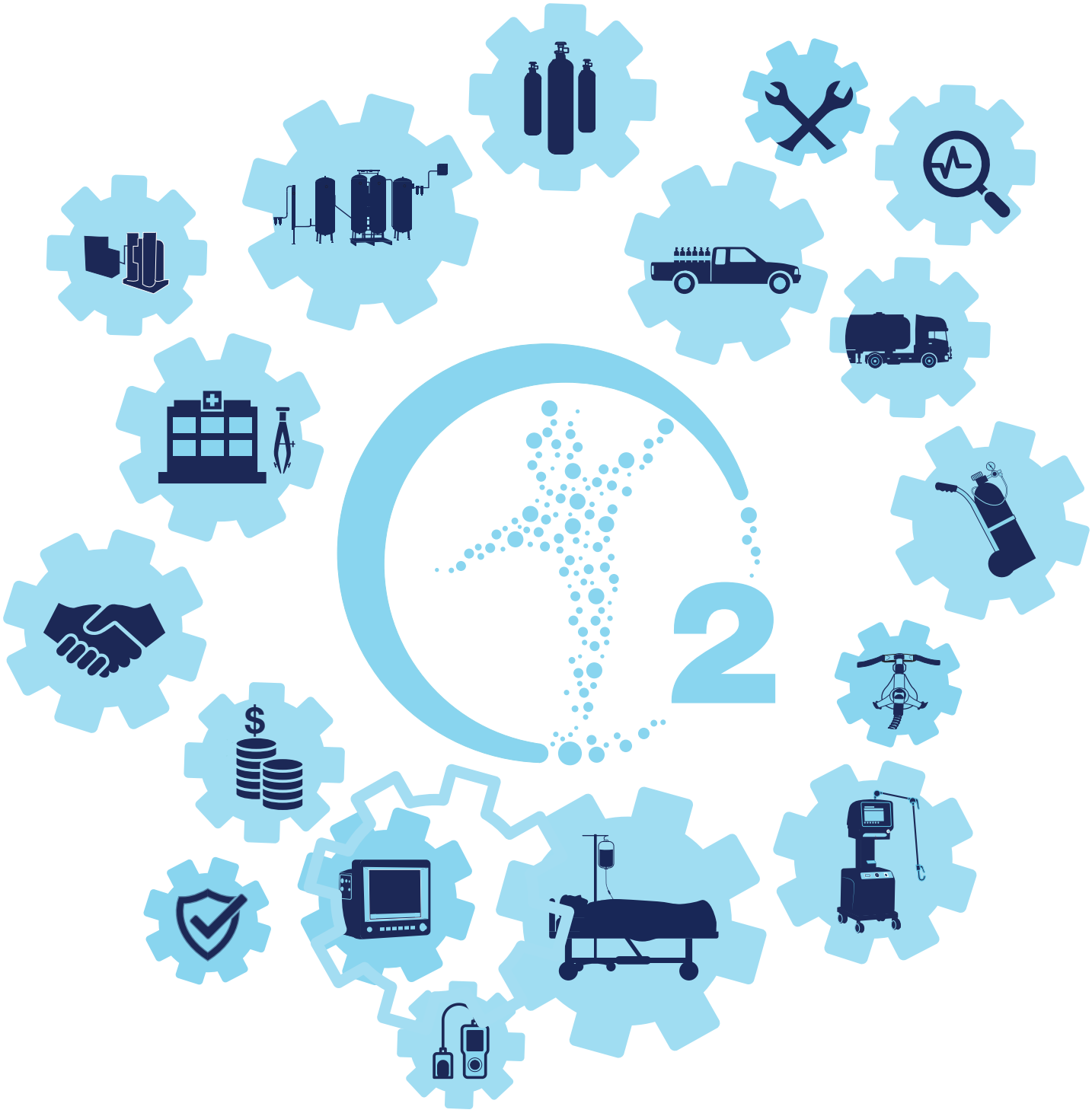
Developing key performance indicators for the medical oxygen ecosystem through Delphi consensus

17 February 2023



World Health Organization

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WHO continues to monitor the situation closely for any changes that may affect this document. Should any factors change, WHO will issue a further update. Otherwise, this document will expire 2 years after the date of publication.

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Contents

Acknowledgements

Authors

Janet V Diaz, Constance McDonough-Thayer (Clinical Management and Operations Unit, Country Readiness Strengthening [CRS], Health Emergencies Programme [WHE], World Health Organization [WHO] headquarters); Bridget C Griffith (Clinton Health Access Initiative [CHAI], United States); Zachary Panos (Johns Hopkins Bloomberg School of Public Health; CHAI, United States).

ACT-A Oxygen KPI Working Group

Antoine Maillard (Alliance for International Medical Action); Felix Lam (CHAI); David Lowrance (The Global Fund); Alex Rothkopf, Tanya Lalwani (PATH); Anne Detjen, Habtamu Tolla (United Nations Children's Fund); Katerina Galluzzo, Tanya Guenther, Jackson Hungu, Ombeni Mwerinde (Unitaid); Melissa Bochnowicz, Nikki Tyler (United States Agency for International Development); Jamie Rylance, Alejandra Velez Riuz Gaitan, Vanessa Cramond (Clinical Management and Operations Unit, CRS, WHE, WHO headquarters).

Moderation: Srinivas Murthy (University of British Columbia, Vancouver, Canada).

We thank all participants who contributed their time and expertise to this Delphi exercise.

Contributions

Janet V Diaz, Constance McDonough-Thayer and Alejandra Velez Ruiz Gaitan, with support from the ACT-A Oxygen KPI Working Group wrote the research protocol; Bridget Griffith, Constance McDonough-Thayer and Zack Panos wrote the manuscript; Zack Panos configured the survey using DelphiManager and Bridget Griffith configured the survey using REDCap; Constance McDonough-Thayer and Zack Panos performed the data analysis; Srinivas Murthy moderated the sessions for consensus; all authors contributed to writing, and approved the final version.

Conflicts of interest

The authors declare there are no conflicts of interest in relation to this study.

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Correspondence

oxygen@who.int

Abbreviations

ACT-A	Access to COVID-19 Tools - Accelerator
BiPAP	bilevel positive airway pressure
CHAI	Clinton Health Access Initiative
COVID-19	coronavirus disease 2019
CPAP	continuous positive airway pressure
EML	Essential Medicines List
GMP	good manufacturing practices
HFNC	high-flow nasal canula
IMV	invasive mechanical ventilation
KPI	key performance indicator
LMICs	low- and middle-income countries
REDCap	Research Electronic Data Capture
SARS-CoV-2	severe acute respiratory syndrome coronavirus 2
SpO_2	oxygen saturation
UN	United Nations
WHO	World Health Organization

Abstract

Background

The COVID-19 pandemic has highlighted the importance of, and lack of equitable access to, medical oxygen throughout the world. Since February 2020 through February 2022, US$ 323 422 372 was invested in biomedical supplies for oxygen and respiratory therapy by various agencies. Despite this large global investment, no key performance indicators (KPIs) exist to track and monitor the impact of these investments.

Methods

Between March and November 2022, the WHO conducted a three-part series of online surveys to identify and gain consensus on critical KPIs for monitoring the global medical oxygen response. Participants represented diverse industries and all WHO regions were represented. The first two surveys were conducted via the Delphi method, and the final survey was conducted using REDCap. Predetermined thresholds for consensus and simple majority were developed for the surveys.

Findings

Four out of four proposed domains gained consensus in survey 1. In survey 2, 24 out of 32 indicators gained consensus by participants, and three indicators were deleted by the study team. In survey 3, participants determined that eight of the 24 indicators needed prespecified numerical thresholds. The thresholds will be developed in 2023. Through the three surveys, participants aligned on a list of 24 critical KPIs for monitoring the global medical oxygen response.

Interpretation

This study resulted in the development of the first-ever list of KPIs to monitor the global medical oxygen response. These indicators must be operationalized and actively used to ensure proper monitoring of the oxygen response. The indicators should be periodically revisited to ensure that they are relevant and fit-for-purpose as the global medical oxygen response evolves.

Funding

This study was funded by Unitaid. There were no payments to participants.

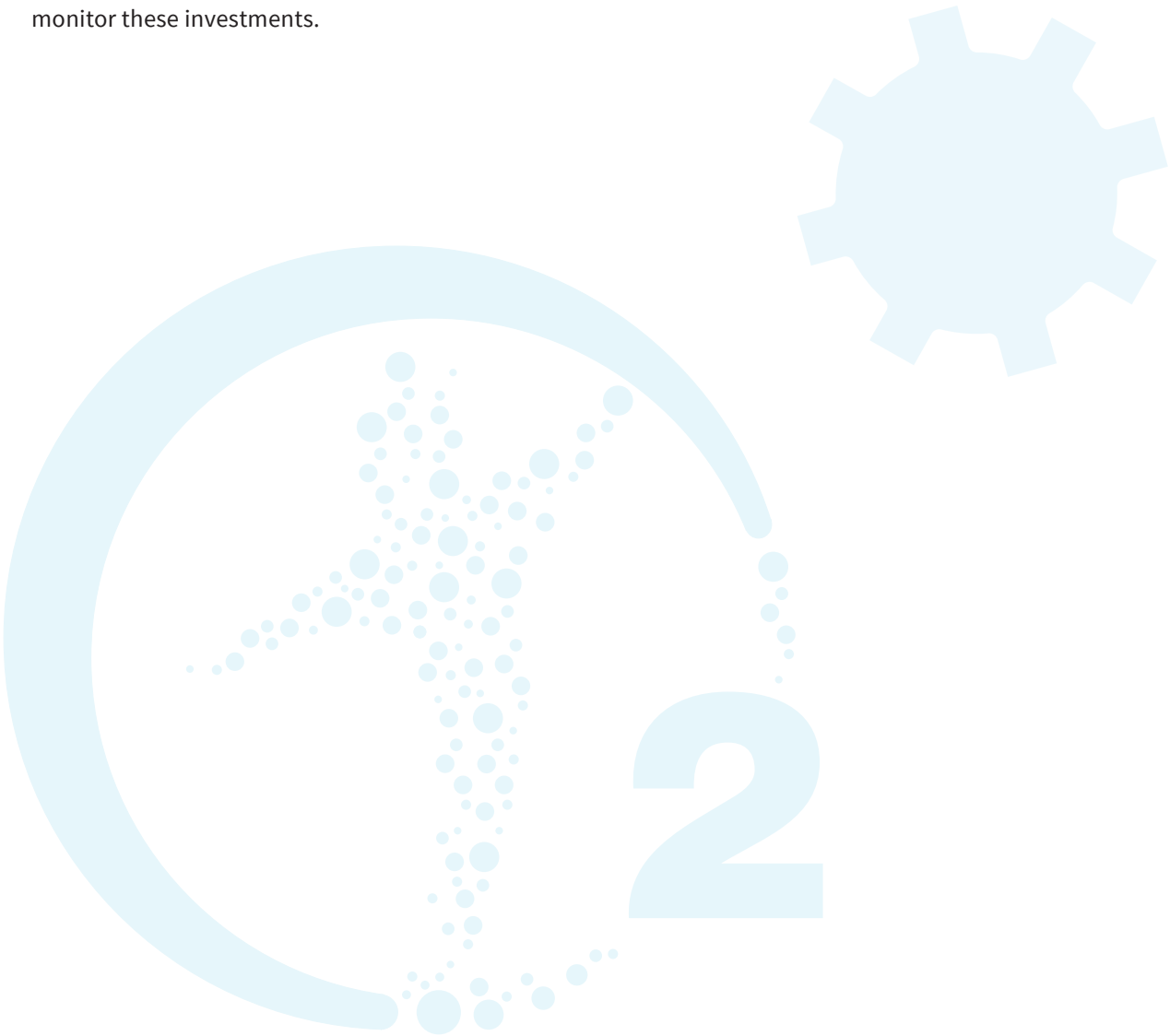
1. Summary

1.1 What is already known about the topic

The COVID-19 pandemic has highlighted the importance of and inequities in access to life-saving medical oxygen and has resulted in US$ 323 422 372 in related investments between February 2020 – February 2022. However, no consolidated list of KPIs exists to date to monitor these investments.

1.2 What this study adds

This study defined the first-ever KPIs for monitoring global investments in medical oxygen. These indicators will be used at global and national levels to measure performance and identify areas for improvement within the global medical oxygen response.



2. Introduction

Medical oxygen is life-saving medicine that is used to treat many conditions, including but not limited to severe or critical infection with SARS-CoV-2 (COVID-19), severe pneumonia in adults and children, trauma, complications of pregnancy, sepsis and other serious infections, and complications of noncommunicable diseases *(1)*. Despite its clinical importance and inclusion on the WHO Essential Medicines List (EML) *(2)*, medical oxygen remains a limited resource in various health care settings across low- and middle-income countries (LMICs) and in some upper-middle and high-income countries *(3, 4)*. The COVID-19 pandemic has highlighted theses inequities in availability and access to this life-saving medicine. The Access to COVID-19 Tools - Accelerator (ACT-A) Therapeutics Pillar prioritized oxygen investments as a major component of the strategic plan launched in October 2021 *(5)*.

As of February 2022, US$ 323 422 372 has been invested through procurement in biomedical supplies for medical oxygen and respiratory therapy. This procurement reflects investments by 10 agencies for 156 countries since February 2020.[1] The biggest investments have been made for oxygen concentrators, high-pressure gas cylinders, invasive and non-invasive ventilators and pressure swing adsorption oxygen generator plants. The United Nations (UN) Supply Chain Task Force, through the WHO Biomedical Consortium, tracks these and other medical oxygen investments by various agencies involved in the global response to COVID-19. However, there is a need for KPIs, at both global and national level, to support donors, international agencies and country governments to measure performance of and identify areas of improvement for key investments in medical oxygen infrastructure.

To develop these KPIs, a three-part survey was conducted between March and November 2022 to establish the relevant domains and indicators to serve as KPIs for global oxygen investments. These indicators are intended to apply to the entire medical oxygen ecosystem and continuum, from financing and policy to sourcing, procurement and operationalization of goods through to patient health impact.

[1] Clinton Health Access Initiative (CHAI); The Global Fund to Fight AIDS, Tuberculosis and Malaria (GF); International Medical Corps (IMC); Pan American Health Organization (PAHO); PATH; United Nations Development Programme (UNDP); United Nations High Commissioner for Refugees (UNHCR); United Nations Children's Fund (UNICEF); United States Agency for International Development (USAID), and World Health Organization (WHO).

3. Methods

3.1 Study design and participants

This study is a prospective, cross-sectional survey that sought to gain consensus on KPIs for medical oxygen investments using the Delphi process. A Delphi study is a protocol-based and methodologically sound way to obtain consensus on an issue by gathering opinions from a diverse range of stakeholders through multiple structured rounds of surveys *(6)*.

The WHO Oxygen KPI Study Team chose to use Delphi methods for this study given the methodologically sound and protocol-based nature of Delphi surveys, and the ability to reach a broad, geographically dispersed audience *(6)*. Delphi surveys are anonymous and iterative, allowing participants to consider their views of a topic in the context of views of their peers while minimizing the risk of conformity bias. Other departments at WHO have successfully used Delphi methods for other COVID-19-related topics, such as developing a clinical case definition for post COVID-19 condition *(7)*.

There was no specific inclusion or exclusion criteria for participation in the study, and the study team utilized multiple channels including e-mail, presentations to the Every Breath Counts Coalition, LinkedIn and Twitter to recruit a diverse range of participants with experience in the medical oxygen field. The study team attempted to ensure that a wide variety of stakeholders had the opportunity to participate in the study, focusing on geographic as well as occupational diversity within relevant fields pertaining to medical oxygen.

3.2 Study procedures

The study consisted of three online surveys, with up to three rounds of voting within each of the surveys, as needed. The first two surveys were completed as Delphi studies using the Comet Initiative web-based DelphiManager software hosted by the University of Liverpool *(8)*. The study team collected and managed data for the third and final survey using REDCap electronic data capture tools hosted at WHO headquarters. REDCap (Research Electronic Data Capture) is a secure, web-based software platform designed to support data capture for research studies *(9, 10)*. Subject matter experts at WHO drafted the initial domains and indicators which then fed into the surveys where user feedback was solicited during the voting rounds. Indicators were added, removed and edited as needed and suggested by participants.

The first survey established the categories, or "domains", for the KPIs, and was concluded after two rounds of voting. In the second survey, participants voted on specific indicators within each of the domains for inclusion as KPIs for global medical oxygen investments. This survey was completed in three rounds of voting and required a consensus meeting to establish the inclusion outcome of indicators that did not reach consensus through the three rounds of voting. In the third survey, participants voted on whether prespecified numerical thresholds for each indicator were needed, or if they could be left open for individual organizations and countries to establish based on their own context and goals. This survey was completed after one round of voting.

Throughout the survey, there were minor edits to the wording of each indicator to improve clarity based on feedback from participants. In survey three, the wording was further changed from a format conducive to the Delphi method to a format that would more closely align with the wording used for the ultimate KPIs.

Survey 1

Participants were given 17 days to complete the first voting round of survey 1. Participants had the ability to add comments or to suggest additional domains for consideration in subsequent rounds of voting. In the second voting round of survey 1, participants only voted on the domains that did not reach consensus in the first round. Per the Delphi process, participants were able to see the vote distribution from the first voting round for the domain included in round two. The second voting round was open for 4 days.

Survey 2

Participants were given 12 days to complete the first voting round of survey 2. Participants had the ability to add comments or to suggest additional indicators for consideration in subsequent voting rounds. In voting round two of survey 2, participants voted on indicators that did not reach consensus in round one, as well as on new indicators proposed by participants in voting round one (seven new indicators). Again, participants were able to see the vote distribution from the first voting round. Participants had 9 days to complete voting round two of survey 2.

A third and final voting round was needed as not all indicators gained consensus after two voting rounds. Ahead of voting round three of survey 2, three indicators were deleted by the WHO Oxygen KPI Study Team. One indicator was removed as it was determined that the wording was incorrect. The other two indicators were removed based on feedback that they were duplicative of other indicators in the set. Participants had 10 days to complete voting round three of survey 2. The WHO Oxygen KPI Study Team convened a focus group, consisting of members of the WHO Oxygen KPI Working Group and moderated by an external body, to debate the inclusion of the remaining seven indicators. Through this focus group, it was decided to include two of the seven remaining indicators.

Survey 3

Participants were given 11 days to complete the third survey. This survey was conducted in REDCap rather than DelphiManager as questions required a binary answer. In this survey, a simple majority (over 50% of the vote for a given indicator) was used to determine whether an indicator should have a predetermined numerical threshold. The thresholds were not set before the survey, and WHO plans to convene a group of experts to develop these thresholds in 2023 for the indicators where a majority of participants voted that a prespecified numerical threshold was needed.

3.3 Statistical plan

In survey 1 and survey 2 participants voted using a nine-point Likert scale, with a score of 7–9 indicating that a component (domain or indicator for surveys 1 and 2, respectively) was “critical”, 4–6 indicating a component was “important but not critical”, and a score of 1–3 indicating that a component was of “limited importance”. Participants were also able to select that a component was “not my expertise” or to leave the question blank. The primary goal was to establish consensus on the inclusion or exclusion of domains and indicators. Consensus was defined as 70% or greater of responses falling between 7–9 or 1–3 for each domain or indicator. 70% or greater of responses falling between 7–9 served as the inclusion criteria, and 70% of greater of response falling between 1–3 served as the exclusion criteria. When 70% was not reached for either of these thresholds, the question was repeated in a subsequent round.

Votes of “not my expertise” were excluded from the denominator. Domains and indicators that reached consensus in the first voting round of each survey were excluded from the subsequent iterative voting rounds. When consensus for a domain or indicator was not reached after three rounds, a focus group was convened with a random selection of study participants to align on inclusion or exclusion of a given domain or indicator.

In survey 3, participants voted that either “a predetermined threshold is needed” or “a predetermined threshold is not needed” for each of the indicators. A simple majority of over 50% of the votes was used to determine whether a global predetermined numerical threshold was needed for each indicator.

3.4 Primary and secondary endpoints

The primary objective was to achieve consensus for inclusion or exclusion of domains and indicators for use as global KPIs for medical oxygen investments. The secondary objective was to determine if predetermined numerical thresholds for each indicator were needed.

4. Results

Consensus was reached to include all four initially proposed domains in survey 1. In survey 2, consensus was reached to include 24 indicators out of 32 initially proposed. In survey 3, participants voted for eight of the 24 indicators needing prespecified numerical thresholds.

Survey 1

In the first voting round of survey 1, consensus was reached to include three of the four initially proposed domains. Consensus was reached to include the fourth and final domain after the second voting round of survey 1 (Table 1). A total of 57 participants completed the first voting round of survey 1 (the full list of the number of participants completing each survey round can be found in Table 3). Participant demographics are listed in Table 2 – there were participants from all six WHO regions including 31 countries (Table 4).

Survey 2

In the first voting round of survey 2, consensus was reached to include 11 of 25 proposed indicators, and seven additional indicators were suggested by participants and added to the survey for voting in subsequent rounds. At the end of voting in round two, consensus was gained on seven additional indicators, bringing the total number of indicators with consensus to 18 of 32. Three indicators were removed by the WHO Oxygen KPI Study Team between voting rounds two and three. In voting round three, consensus was reached on four additional indicators, bringing the final number of indicators with consensus after three rounds of voting to 22 out of 29.

Two additional indicators gained consensus after the final consensus focus group, bringing the total number of indicators with consensus to 24 of 29 (Table 5). Table 6 shows the eight indicators that did not gain consensus and the three that were deleted by the WHO Oxygen KPI Study Team.

Survey 3

Only one round of voting was conducted for survey 3. Participants voted for eight out of 24 indicators needing prespecified thresholds (Table 5).

Table 1. Domains that achieved consensus during survey 1

	Voting rounds of survey 1 where consensus was gained	
Domain name	**One**	**Two**
Procurement		●
Operations	●	
Oxygen ecosystem	●	
Patient health impact	●	

Table 2. Demographics of participants in survey 1, round 1

Characteristic		**Survey 1 (N = 57)**	**%**
Sex	Male	33	58%
	Female	22	39%
	No response	2	3%
Age	20–29	5	9%
	30–39	18	32%
	40–49	15	26%
	50–59	12	21%
	60–69	4	7%
	No response	3	5%
WHO region	African Region	15	26%
	Region of the Americas	15	26%
	South-East Asia Region	6	11%
	European Region	14	25%
	Eastern Mediterranean Region	2	3%
	Western Pacific Region	5	9%
Profession	Public health specialist	19	33%
	Clinician	18	32%
	Biomedical or clinical engineer	9	16%
	Supply/logistics specialist	3	5%
	Engineer (other)	2	3%
	Procurement specialist	1	2%
	Other	5	9%

Characteristic		Survey 1 (N = 57)	%
Institution	United Nations agency	17	30%
	Nongovernmental organization	17	30%
	Academic institution	9	16%
	Donor agency	3	5%
	Public hospital	3	5%
	Ministry or department of health	1	2%
	Private hospital	1	2%
	Other	6	11%

Table 3. Number of respondents completing each survey round

Survey	Round	Respondents
1	1	57
	2	30
2	1	35
	2	28
	3	15
3	1	19

Table 4. Global distribution of study participants

Argentina
Australia
Brazil
Canada
Congo
Congo (Democratic Republic of the)
Denmark
Ethiopia
France
Germany
Ghana
Honduras
India
Iran (Islamic Republic of)
Kenya
Liberia
Mongolia
Nepal
New Zealand
Nigeria
Philippines
Saudi Arabia
Senegal
Slovakia
Spain
Sweden
Switzerland
Tanzania (United Republic of)
Uganda
United Kingdom of Great Britain and Northern Ireland
United States of America

Table 5. Key performance indicators that achieved consensus during survey 2

Domain	Indicator	Voting rounds of survey 2 where consensus was gained				Prespecified numerical threshold required?
		Round 1	Round 2	Round 3	Focus group	
Operational	Total amount of medicinal oxygen produced and/or stored (in m3) by the commissioned oxygen system (new/repaired) per 24 hours out of all the medicinal oxygen that is needed (in m3) per 24 hours at a given facility.	●				
Operational	Number of health facilities that received technical support (e.g. biomedical or mechanical engineering) for maintaining oxygen systems out of the total number of health facilities with oxygen systems.	●				
Operational	Number of hours per day that the oxygen system (new/repaired) is operating.	●				YES
Operational	Number of oxygen systems (new/repaired) that remain functional 1 year after installation/repair.	●				YES
Operational	Number of oxygen systems that are non-functional due to a lack of reliable and continuous electricity out of the total number of oxygen systems that are non-functional (for any reason).	●				
Operational	Amount of medicinal oxygen consumed (in m3) per 24 hours out of all the medicinal oxygen that is produced and/or stored (in m3) by the commissioned oxygen system (new/repaired) per 24 hours at a given facility. *(Suggested by participants during survey 2 voting round 1)*		●			
Oxygen ecosystem	Inclusion of oxygen on the Essential Medicines List (EML) in countries with oxygen investments.				●	
Oxygen ecosystem	Number of beds at the facility equipped with a functional oxygen supply out of the total number of beds at the facility.		●			YES
Oxygen ecosystem	Number of clinical staff trained on oxygen therapy at the facility level out of the total number of clinical staff at the facility level.	●				YES
Oxygen ecosystem	Number of countries that have oxygen included as part of national health strategy documents and/or plans.		●			
Oxygen ecosystem	Number of countries that include aspects of the oxygen ecosystem in their health financing.	●				
Oxygen ecosystem	Number of health facilities with functional oxygen systems out of the total number of health facilities.	●				YES
Oxygen ecosystem	Number of technical staff trained on oxygen systems operation and maintenance at the facility level out of the total number of technical staff at the facility level.	●				

Domain	Indicator	Voting rounds of survey 2 where consensus was gained				Prespecified numerical threshold required?
		Round 1	Round 2	Round 3	Focus group	
Oxygen ecosystem	Number of health facilities that have functional oxygen analysers and other testing and maintenance tools out of all health facilities supplying oxygen. *(Suggested by participants during survey 2 voting round 1)*		●			
Patient health impact	Number of hospitalized patients receiving oxygen therapy and having their oxygen saturation monitored at least twice per 24 hours out of the number of hospitalized patients receiving oxygen therapy.		●			YES
Patient health impact	Number of COVID-19 patients treated with oxygen therapy (by any delivery device; including nasal canula; HFNC; BiPAP; CPAP; IMV; etc.) at the facility out of all COVID-19 patients needing oxygen therapy.			●		
Patient health impact	Number of patients that have had their oxygen saturation monitored with pulse oximetry at their first point of contact at facility per 24 hours out of the total number of patients evaluated at first point of contact per facility.	●				YES
Patient health impact	Number of patients treated with oxygen therapy (by any delivery device; including nasal canula; HFNC; BiPAP; CPAP; IMV; etc.) at the facility out of all patients needing oxygen therapy at the facility.	●				
Patient health impact	Number of health facilities that have functional pulse oximeters out of all facilities. *(Suggested by participants during survey 2 voting round 1)*		●			YES
Patient health impact	Number of hospitalized patients receiving oxygen with $SpO_2 < 93\%$ at 24 hours post-admission out of the total number of hospitalized patients receiving oxygen therapy. *(Suggested by participants during survey 2 voting round 1)*			●		
Procurement	Time it takes for the items to arrive at the facility from the destination agreed to in the purchase order (for orders where destination agreed in purchase order is not facility).				●	
Procurement	Number of goods that have been delivered out of all goods ordered.		●			
Procurement	Value of funds awarded for the procurement of oxygen supplies out of all funds made available for procurement of oxygen supplies.			●		
Procurement	Value of funds spent for procurement of oxygen supplies out of the total funds awarded for procurement of oxygen supplies.			●		

Table 6. Key performance indicators that did not gain consensus or were deleted by the WHO Oxygen KPI Study Team

Domain	Indicator
Operational	Time it takes (in days) for goods that have been commissioned (new/repaired) to become operational at the facility.
Operational	Number of medical oxygen productions plants, liquid oxygen bulk tanks, or high-pressure cylinders at the facility level that are complying with good manufacturing practices (GMP) out of all of these sources in countries with oxygen investments. **(Deleted by study team)**
Oxygen ecosystem	Price ceilings for medical oxygen in countries with oxygen investments.
Patient health impact	Number of patients on oxygen with documentation every 8 hours, including O_2 dose and SpO_2.
Patient health impact	Number of facilities that have digital solutions for information management regarding patient care out of the total number of facilities.
Patient health impact	Number of patients who died from pneumonia while being treated with oxygen therapy out of all patients with pneumonia treated with oxygen at the facility level on a monthly basis in countries with oxygen investments. **(Deleted by study team)**
Patient health impact	Number of patients who died with hypoxaemia or pneumonia symptoms while being treated with oxygen therapy out of all patients treated for pneumonia or hypoxemia with oxygen at the facility level on a monthly basis in countries with oxygen investments. **(Deleted by study team)**
Procurement	Number of items that arrived at the destination agreed to in the purchase order within the prespecified timeframe out of all items that arrived at the destination agreed to in the purchase order.

5. Discussion

This study defined a list of KPIs to monitor the global medical oxygen response (Table 5). Through a protocol-based (Delphi) sequence of surveys, an initial list of 32 KPIs were narrowed down to 24 that were deemed critical by a diverse array of participants. Participants concluded that eight of these 24 KPIs need predetermined numerical thresholds.

This study has some clear strengths, including the use of the Delphi method, which enables iterative and anonymous consensus-building while allowing participants to adjust their position based on the aggregate votes of their peers. The Delphi method has been used for other COVID-19-related consensus-building processes, such as the development of a clinical case definition for post COVID-19 condition.

In terms of limitations regarding the process, while the WHO Oxygen KPI Study Team made strong efforts to encourage widespread participation from varied professionals working in the medical oxygen field, overall participation was lower than anticipated. Additionally, participants from UN agencies and nongovernmental organizations were disproportionally represented compared with other categories such as ministries or departments of health. This may limit the applicability of the KPIs at national level in some settings. Future efforts to define KPIs could include more targeted recruitment efforts to make sure the views of these underrepresented groups are included.

A brief literature review was conducted to determine whether there were already established global KPIs for medical oxygen, and while it concluded that there were some specifically for pneumonia, none were found for the broader global medical oxygen response. This is the first study of its kind to develop KPIs for the global medical oxygen response.

Future research opportunities include the critical evaluation of the use of these KPIs, as well as using these KPIs to evaluate the global medical oxygen response. These KPIs should also be revisited in the future to ensure that they are still fit-for-purpose, and to determine if additional KPIs should be added as the global medical oxygen response evolves.

The next steps past this study will be around the utility of these indicators. The appropriate monitoring and evaluation stakeholders vary based on the metrics and the applicability ranges from a facility to global use-case. At a high-level, these will be used to monitor the global investment in oxygen as a way to understand how the community supporting the scale-up of oxygen is delivering regarding use of funds, timeliness and provision of operational support. At the facility and country level, these will be disseminated and support will be provided where needed to facilitate the use of these indicators as a way to assess and monitor performance and progress around the oxygen ecosystem.

6. Conclusion

The COVID-19 pandemic has drawn global attention to the importance of, and lack of access to, medical oxygen in countries around the world. Measuring and assessing the investments in medical oxygen made during the COVID-19 pandemic is critical to understand their impact and ensure that future investments are made responsibly. This study resulted in the first-ever list of KPIs to monitor the global medical oxygen response. However, these KPIs must be operationalized, and revisited, to positively impact the lives of people around the world who need medical oxygen.

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