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COMMISSION ON MEDICAL OXYGEN SECURITY

COUNTRY CASE STUDY

Uganda

The evolution of the medical oxygen supply chain

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Case study focus

Medical oxygen systems are complex, covering oxygen production, distribution, storage, and patient delivery. Each of these steps in the supply chain can involve different technologies, multiple public and private actors, and various regulations and standards. Therefore, understanding how these components integrate into an effective and efficient system is critical for ensuring medical oxygen security across the health system. This case study focuses on the current state of the medical oxygen supply chain at multiple levels of the Ugandan health system while tracing the evolutionary journey taken since the pre-COVID-19 period in 2018. It aims to provide insight into whether the recent investments in increasing the nation's medical production capacity has translated into improved patient access through a strengthened oxygen system.

Key messages

Prioritizing medical oxygen on policy agendas

- *Medical oxygen needs to be prioritized in the public health sector agenda by increasing financial commitments in annual recurrent and capital budgeting at the national, sub-national and facility levels.*
- *Robust budgeting requires health information systems that capture trends in consumption. This will necessitate integrating medical oxygen data capture into routinely collected data in district health information systems (DHIS-2).*
- *There is need to need for civil society advocacy in order to sustain medical oxygen issues on the public sector agenda amidst the array of competing needs across health conditions in Uganda.*

Health workforce gaps

- *Health workforce gaps in medical oxygen security emerged as a cross-cutting constraint in the case of Uganda. Particularly, dependence on expertise from foreign-based equipment suppliers in servicing and repairing PSA plants emerged as a major issue. High-impact interventions such as peer to peer mentorships, regionally based support teams and workshops could be worthwhile considerations.*
- *From a biomedical engineering perspective, building a critical mass of qualified biomedical engineers that are competent in medical oxygen equipment management, including providing tertiary training institutions-level attachments, should be a priority.*

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Country context

Demography, economy and epidemiology

Uganda is a landlocked country in East Africa with a population of approximately 45.9 million based on the 2024 census,(1) and maintains one of the highest population growth rates in the world at 2.9%. The country has achieved substantial gains in economic development and improvements in health outcomes over recent decades, including reductions in under-5 mortality at 52 deaths per 1000 live births, infant mortality at 36, and neonatal mortality at 22 and pregnancy related mortality ratio of 228 deaths per 100,000 live births.(2,3) However, it remains one of the least developed countries in the world with as gross national income per capita of US$974 in 2022.(4) Poverty levels are high with 20.3% and 41.2% of the population below the national and international poverty line, respectively.(4) Uganda's health system bears a substantial burden of preventable and poverty-related diseases including malaria, HIV/AIDS, and tuberculosis.

In the financial year of 2022/2023, neonatal conditions were the leading cause of health facility deaths across all age groups, accounting for 10.3% of mortality, followed by malaria (7.4%), pneumonia (5.3%), anaemia (3.9%), road traffic injuries from motorcycles and vehicles (2.3%), and septicaemia (1.9%). In the same period, the leading causes of hospital admission were malaria, pneumonia, anaemia, septicaemia, neonatal conditions, road traffic accidents and other injuries, complications of pregnancy and obstructed labour, sickle cell disease and asthma in descending order of magnitude.(4)

Key messages cont.

- *Delegating responsibility for the maintenance and servicing of PSA plants across the country to the National Medical Stores would enable build technical expertise and attract dedicated budgets given its unique status in Uganda's health commodity supply chain.*
- *Policy and programming interventions for medical oxygen security in Uganda were heavily donor-funded and donor-driven which calls for urgent consideration of more predictable and government led health financing based on efficient and optimal use of public resources.*

Centralization of oxygen governance systems

- *The centralization of oxygen production and distribution appears to stem from differential funding arrangements for central production relative to hospital-based PSA plant systems. NMS and JMS are paid for the oxygen production (JMS can sell its product) from government or the private sector.*
- *Public facilities with PSAs have found it cheaper to collect "free" oxygen cylinders from NMS, than producing oxygen on-site due to high operational costs. This model also favours NMS that stands to gain from supplying (and therefore billing) higher volumes.*
- *The issue of parallel investments in centralization production, and on-site hospital-PSAs with competing incentives need harmonization at an 'upstream' level.*
- *There is need to engender a broader health systems strengthening approach to medical oxygen supply chains in terms of governance arrangements and financing pathways.*

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TThese conditions are commonly associated with hypoxaemia (low blood oxygen) and other complications for which prompt detection and management with pulse oximetry and oxygen therapy is a basic standard of care.5,6 Low oxygen levels in the blood, occurs in various acute and chronic disease conditions throughout the life course,(5,6) significantly contributing to their severity and mortality. It affects patients regardless of age, sex, aetiology, or geographical region.

Over the last three fiscal years, the major causes of institutional deaths have not significantly changed. However, despite remaining as the leading cause of mortality, there's been a notable 36.8% decrease in absolute deaths from neonatal conditions, dropping from 5,899 in 2021/22 to 3,730 in 2022/23. This improvement has been attributed to focused interventions, such as the perinatal death notification and reviews, establishment of Neonatal Intensive Care Units (NICUs), and a mentorship program.(4)

Indicator	Recent value	Data source (year)
Total population	45,791,461	Uganda Bureau of Statistics (2022)
Total under-five population	7,921,923	Uganda Bureau of Statistics (2022)
Under-five mortality rate	52/1,000 live births	Uganda DHS (2022)
Maternal mortality ratio	189/100,000 live births	Uganda DHS (2022)
Life expectancy at birth (m:f)	60:65	World bank (2021)
GDP	$US 45.6 billion	World bank (2023)
Healthcare expenditure per capita	$US 22	WHO (2022/2023)
Income status (income per capita)	$US 1046	Uganda Bureau of Statistics (2022)
Gross National Income per Capita	$US 840	World Bank (2021)

Table 1: Description of key population health indicators in Uganda. DHS = Demographic and Health Survey; $US = US dollars

Health system

Uganda has a decentralized health system, comprised of both public and private health providers. The Ministry of Health is responsible for setting policies and strategic direction, while

Local Governments are responsible for service delivery. The Districts and Health Sub-Districts are responsible for leadership in the planning and management of health services, supervision and quality assurance, provision of technical, logistic and capacity development support. Uganda's has a tiered health system based on the health services scope they provide and the catchment area they are intended to serve. On the lower rung of the formal health system are health centre level II to level IV; then General hospital, Regional Referral hospital and National Referral hospital.

For the public facilities, the National and Regional Referral Hospitals report to the Central Government; while General Hospitals and Health Centres (II—IV), report to the Local Governments. Uganda has a total of 6,404 Health facilities and special clinics. 48.0% (n=3084) of health facilities are Government owned, 15.0% (947) are private not-for-profit and the remaining 37.0% (n=2373) are private-for-profit facilities. At community level, volunteers chosen within the community by the residents form a village health team that largely provides health promotion services and community sensitization and mobilization.

In terms of financing, there are various mechanisms through which health services are funded in Uganda. These include public expenditure, private expenditures (that primarily consists of out-of- pocket payments and health insurance) and external donor support.(7) Government allocations to health have fallen over time, in 2018/19, the government allocated 7.0% of the national budget to the health sector which is far below the 2001 Abuja declaration target of 15%.

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From the US$144 per capita annual budget allocation, approximately US$10 per capita was allocated to the health sector. This allocation to health is also significantly lower than the estimated requirement of US$86 per capita needed to provide essential health services in low-income countries.(8) In 2019, the proportion of the current health expenditure in the country showed that the Government of Uganda was only funding 17.2% of the health sector budget. (7) The low government funding led to gaps in the quality of services provided and as a result, hindered access to services within the public health system. The domestic private health expenditure in the form of out-of-pocket payments and health insurance was at 41.4%. (9)

The Parliament of Uganda passed the National Health Insurance bill as a private members bill amidst protests by the Ministry of Health. However, the President refused to assent to the bill and returned it to parliament. Presently, health insurance has a very low penetration amongst the population with approximately 5% of private health expenditure going towards private health insurance schemes. The low insurance coverage is attributed to several reasons; there is no mandatory requirement for health insurance and the majority of the population are not afforded the opportunity to benefit from it, those in the informal sector who are the largest population group. Existing health insurance schemes are promoted as employee benefits by a handful of employers.(9)

The National Scale-up of Medical Oxygen Implementation Plan (2018-2022) in Uganda was a substantial initiative aimed at improving the availability and accessibility of medical oxygen across the country.(10)

The expiration of this plan marked an important moment to reflect on its accomplishments and the challenges that remain. The plan required a significant financial investment, totalling approximately US$1.2million (4,509,305,909 Ugandan Shillings). The Ugandan Government committed a substantial portion of this budget, approximately US$8.6 million (32,669,838,631 Uganda Shillings), demonstrating a strong governmental commitment to healthcare infrastructure and the well-being of its citizens. However, the plan also encountered a notable funding gap of US$3.1 million (11,839,467,278 Uganda Shillings). This gap highlights the challenges in mobilizing adequate resources for such crucial healthcare initiatives. A successor plan for 2023-2027 has now been published.(11)

COVID-19

Uganda reported its first case of COVID-19 on 21st March 2020. The country thereafter experienced a rapid rise in the number of cases to 52, most of whom were imported cases from international quarantine. By 6th May 2020, the country had recorded 100 cases, most of which (89%) were imported amongst truck drivers. As of June 2021, Uganda was experiencing a second wave of the pandemic and more non-pharmaceutical interventions were reinstated to control spread. By 23rd January 2023, Uganda had registered 171,983 cases and 3,632 deaths.

Uganda implemented a number of measures to control the pandemic including imposing lockdowns in March 2020. The events as they unfolded are summarized in Figure 1. The COVID-19 pandemic underscored the insufficient affordability and sustainability of

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medical oxygen on a national scale, where the extraordinarily high clinical demands at hospitals surpassed the available oxygen supply, leading to preventable deaths. Those challenges were exacerbated by existing issues within the healthcare system, including inadequate human resources, financial constraints, infrastructural deficiencies, and supply chain and logistical problems, an additional reminder that increasing access to medical oxygen to those who need it is a complex problem.

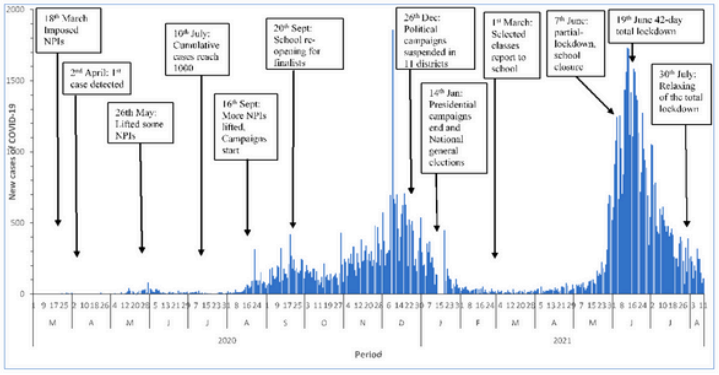

Figure 1: Timeline of key COVID-19 events

The medical oxygen supply chain of Uganda

The Uganda Ministry of Health launched its first National Medical Oxygen Scale-up Plan in 2018. Before this, medical oxygen was not a national priority, and access remained limited. Until 2016, oxygen concentrators were the primary source, leaving patients without high-flow oxygen when demand was high or during power outages.

The 2018 plan introduced a mixed-source model incorporating oxygen concentrators, Pressure Swing Adsorption (PSA) generators, and limited liquid oxygen. Several PSA generators were installed, a process accelerated by the COVID-19 pandemic. Currently, 33 PSA generators operate nationwide, with capacities ranging from 15m³/hour to 100m³/hour. By June 2024, 27 additional PSA generators were in various stages of installation. Two liquid oxygen cryogenic tanks now serve as backup supply. Oxygen concentrators remain part of the national system.

However, 75% of medical oxygen is still supplied via cylinders refilled at PSA plants in regional hospitals, central medical stores, and an accredited private steel industry. Distribution follows a hybrid model: a hub-and-spoke system where cylinders are refilled at regional hospitals and a milkman system where the central stores exchange filled cylinders with empty ones at health facilities.

Multiple sources of medical oxygen

This case study found that at the tertiary level of care, Pressure Swing Absorption (PSA) oxygen generators are a principal source of medical oxygen production, more so in government funded health facilities. The Ugandan Government has established PSA plants at major public Regional Referral Hospitals (RRHs) across the country, with over 17 PSA plants established at the tertiary level of care in Uganda's across major geographic sub-regions.

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Interview participants indicated that the public PSA plants established at sub-national level across Uganda are intended as regional supply hubs for lower-level facilities including general hospitals and health centres level IV, III and II. The PSA plants are expected to produce enough medical oxygen to serve the Regional Referral Hospitals where the greatest demand for the medical oxygen is expected, while simultaneously acting as a supply hub for the lower-level facilities within their catchment via oxygen cylinders. RRHs have greater demand for medical oxygen due to having multiple stand-alone care units such as Accidents and Emergency wards, high dependency units and specialized care service units such as intensive care units and oncology units.

For the private not-for-profit sector, the Joint Medical Stores (JMS) - a specialized medicine and health technologies agency founded in 1979 by the Catholic and Protestant churches as a complimentary procurement, warehousing and distribution player to the publicly funded National Medical Stores. In August 2022, JMS established PSA oxygen generators in Kampala, the administrative, commercial and capital city of Uganda to address the prevalent challenge of inadequate access to medical grade oxygen in Uganda, exacerbated by the COVID19 pandemic.

JMS supplies medical oxygen primarily to health facilities accredited to the Uganda Catholic and Protestant Medical Bureaux (also referred to as private not-for-profit health facilities) principally through oxygen cylinders. It is important to note that a handful of tertiary private not-for-profit facilities in Uganda such as Nsambya Hospital located in the Ugandan capital and Lacor Hospital in Northern Uganda also have on-site PSA plants. For private-for-profit facilities, the JMS is a major source of medical oxygen such as in the case of Nakasero Hospital, a top-tier private hospital, in the Ugandan capital.

"With regard to PNFP [private not-for-profit] facilities, Joint Medical Stores is the main supplier. JMS has a PSA plant with a production capacity of 38 nanometer cubed. They have two plants both with a capacity of 19 nanometer cubed which gives us 38 nanometer cubed. That is what JMS contributes to the national production pool. The other two PNFP plants which we have in Uganda we have is the one with a capacity of 15 nanometer cubed at Nsambya Hospital and Holy Innocents a paediatric hospital in Mbarara in South Western Uganda. There is also one based at Lacor Hospital in Northern Uganda with a capacity of 11 nanometer cubed. That is the capacity we have in the private not for profit sector." Ministry of Health Official

Interviewees reported that Roofings Uganda Limited, one of the largest steel manufacturers in Uganda, produces high volumes of medical oxygen and offers it to public facilities at no charge on-site once empty cylinders are provided for refilling. Since the second wave of the COVID-19 pandemic in Uganda in March 2020, Roofings Uganda has been a major supplier to the National Medical Stores (NMS) which re-distributes the oxygen through cylinders to facilities in need across Uganda.

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"We have to give credit to Roofings Uganda. During the second wave of the COVID-19 pandemic they provided us with 35,000 oxygen cylinders. They supplied these cylinders to over 168 facilities across Uganda for both public and private facilities. Also NMS was getting their supply for national distribution initially from Roofings actually that was before they opened their own PSA plant in February 2024."
Biomedical engineer, Ministry of Health

Our national-level informants also revealed that there were a handful of private firms based in the Ugandan capital which produced medical oxygen on demand such as Oxygen Uganda which largely produced industrial oxygen but could produce medical grade oxygen on order. Our interviewees also reported that the National Medical Stores had already completed construction of a liquid oxygen plant with the capacity to 'produce 25 oxygen cylinders per hour'. This was intended as a backup for the established PSA plants countrywide. However, this plant had not yet started oxygen production.

"As a country we budgeted that we shall have a 60,000 liters' capacity liquid oxygen tanker at National Medical Stores as a backup for all our PSA plants. As a country, if our PSA plants break down, you need uninterrupted oxygen supply. The liquid oxygen plant we have is what we call chimerical oxygen, it is refilled with supplies from outside of Uganda once a year and when it is full and we assume the evaporation rate will be 2% lost in a calendar year." Ministry of Health worker

Oxygen concentrators emerged as the second most important source of medical oxygen at the point of service delivery based on the facilities we visited. Health workers indicated they elect to use concentrators due to their sheer simplicity owing to their ready-to-use attribute. Several of the concentrators we observed in the facilities we visited were developed for home-use and were not intended for multiple users, as they were being used in hospital settings. We only found a few that were meant for multiple users. Nurses reported that concentrators frequently broke down due to overuse and due to having a poor maintenance regime.

Cylinders as the backbone of distribution

We found that in Uganda, the medical oxygen distribution system is principally cylinder-based. Bedside cylinders are the principal medical oxygen storage unit and the main distribution vehicle. Refills for medical oxygen by private and public producers of medical oxygen is predominantly via bedside cylinders. Whenever there are stock-outs, public or private facilities ask for refills by providing empty cylinders to producers or suppliers of medical oxygen. Roofings Limited offers free medical oxygen supplies to public and private facilities on condition that they provide empty cylinders and are willing to meet the costs of transportation of refilled cylinders.

Our findings suggest that oxygen supplies are indeed freely available at Roofings, but that facilities are frequently unable to meet the financial cost of transportation of refilled oxygen cylinders. A recent case involved Hoima RRH in Western Uganda:

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"There are instances where Regional Referral Hospitals approach us for emergency supplies of medical oxygen when they experience stock outs. However, it is common to invite them to pick the oxygen from here in Kampala but you find they don't have the money for transport. For instance, Hoima RRH made a requisition with us but it wasn't honored in time because they appear to lack operational funds. I am told the problem emanated from Ministry of Finance delaying to release operational funds to them. So those kinds of delays are common but the oxygen is actually available in plenty but transportation is usually the challenge." Program Manager, National Medical Stores

In the majority of the facilities we visited across both private and public facilities, bedside cylinders were, by far, the most common source of medical oxygen on hospital wards. There was a paucity of piping systems for distributing oxygen across the various service points within the facilities we visited, and hence the importance of bedside cylinders in getting the commodity to the patients who need it. Even in facilities with PSA plants, bedside cylinders were the default source of medical oxygen on the wards. The over reliance on oxygen cylinders as the primary source of storage and distribution in Uganda has put immense pressure on the supply of empty cylinders. There were complaints raised by oxygen producers such as JMS and NMS on the quality of empty cylinders presented to them for refills ranging from old age and broken nasals.

"I think we should push for more availability of oxygen cylinders because some of these cylinders are now obsolete and it wears their integrity and sometimes with poor handling they can break, the nasals can break. If there could be a way in which they can purchase more durable and long- lasting oxygen cylinders that would be a very good thing. For example, hospitals can bring about 100 empty cylinders and then about 10 or 12 of them are faulty. So, if the government can purchase more cylinders that would be good. And also, if there could be training programmes for engineers to be to get more knowledge on how to maintain and repair cylinders." Plant Operator, National Medical Stores.

During the process of transporting oxygen cylinders for refills many of them suffer damage due to "manhandling" and lack of practice guidelines for safe transportation of medical oxygen cylinders. Few facilities have specialized trucks for carrying the cylinder in the upright position and many are lost or suffer pilferage during transit to production sites.

"To some extent poor handling of cylinders while they are being ferried to suppliers is causing loss of cylinders and reducing their availability for refill because sometimes when the trollies aren't enough, the technicians at facilities roll the cylinders down on the floor and that's where sometimes the nodes break off. So, it's a challenge. There are vehicles that are specialized in carrying cylinders in an upright and safe position, that should be procured but funding is a common challenge...

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At NMS we procured specialized oxygen transport vehicles because during transportation the knobs can snap off and break. This can be dangerous because this is pressurized air." Program Manager, National Medical Stores.

Operational constraints of running PSA plants

Interviews with national-level informants revealed that over the previous five years the Ugandan Government had been implementing a deliberate strategy of increasing the number of PSA plants, particularly at the tertiary level of care that predated the COVID-19 pandemic. As presented earlier, at the level of public Regional Referral Hospitals, PSA plants were a principal source of medical oxygen, with 17 PSA plants established across Uganda's major sub-regions. Select RRHs such as Mbarara RRH and Fort Portal RRH each had two PSA plants each. At three National Referral Hospitals of Mulago, Kawempe and Kiruddu based in the Ugandan capital, stand-by PSA plants had been set up by private companies as emergency backup.

National-level informants indicated that medical oxygen demands were much higher at the tertiary level facilities compared to the secondary level, given the presence of more ward areas, including intensive care units. Consumption patterns varied across the different service points within a hospital, but the average consumption was described by a participant:

"Medical oxygen is utilized in each of these particular units for example in the OPD you realize the average is about five meters per minute and the rationale here is that commonly in OPD the cases being handled are using a nasal prong and looking at the oxygen flow by nasal prong we are going to find it at zero such that one to five liters per minute is what is used. If the patient is not responding, then you need to escalate to a higher gadget like a simple face mask or you need to escalate to a partial venturi mask or escalate to a nanometer mask which is going to be using around 15 liters per minute. If we take average consumption per patient, then its five liters per minute." Health worker at study health facility.

Frequent breakdowns of newly established PSA plants were consistently reported in the national print media over the previous two years. At Kabale RRH in South Western Uganda, the lone PSA plant had been broken down for close to six months at the time of the study. As a result, Kabale RRH had to procure medical oxygen more than 400 kilometers away, in the capital of Kampala, using cylinders. Interviews with informants highlighted that the paucity of spare parts due to the diverse brands in service was a major constraint and that it was common for breakdowns to last weeks due to the lack of spare parts which often had to be imported. Health facilities were contractually bound to order spares for equipment and associated accessories from the original foreign suppliers. External suppliers engaged 'local agents' to service this equipment. This arrangement denied operational experience of servicing and repairing medical oxygen equipment by a technical cadre on the public sector payroll.

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A key finding of this case study was that PSA plants did not have recurrent budgets for routine maintenance, servicing and repair. Recurrent costs such as electricity supply for PSA plants were not provided for in operations budgets for facilities.

"*There are several operational challenges associated with running PSA plants at facility level. 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 for this in public facilities. Some regional referral hospitals such as Kabale RRH have two plants which increases maintenance costs. Then some hospital PSA plants have failed due to of lack servicing agreements with equipment suppliers. Once they commission the plant the hospital is left to its own devices. There is no after sales support*." Ministry of Health official.

A plant operator at a newly established PSA plant run by NMS with a capacity of producing 30 oxygen cylinders per day elicited that the maintenance requirements for PSA plants were out of reach of most public facilities with constrained recurrent budgets. This was unlike the NMS which is autonomous with a much larger operational budget compared to a typical public facility in Uganda.

"*The maintenance schedules are demanding. We have a weekly servicing routine, monthly and every after six months and after a year according to the manuals. So weekly we make sure that we change the water in the cooling tank, the one that cools the booster compressor that fills the cylinders with oxygen and then we also... do dusting because even when the place is well ventilated sometimes dust comes in so we have to dust the filters. There is a sponger filter where air cooling the compressor that we need to dust with a blower. General cleaning of equipment is weekly. We do general inspections on a regular basis. We have a maintenance guide that we follow*." PSA Plant Operator, National Medical Stores.

At the Joint Medical Stores, it was reported that the monthly electricity bill for running the PSA plant there is more US$10,000 which was hardly affordable for public facilities with multiple competing recurrent needs.

Even when hospitals had operational PSA plants, oxygen delivery systems had been found to be a 'weak link'. Having elaborate piping systems that distributed the medical oxygen to the various service points within a hospital complex was a teething challenge in many public facilities. Leakages in the piping systems were common. A related challenge was that of secondary accessories that moved medical oxygen from production to consumption, including basics such as nasal prongs. Accompanying equipment accessories such as flow meters were often in short supply. The shortage of pulse oximeters had been identified as having a ripple effect on oxygen supply management.

The print media articles in the Uganda national press we reviewed also identified a challenge with the number of cylinders that hospital-based PSA systems can have access to. Most of the cylinders seemed to be tied to centralised oxygen systems such as NMS.

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That is to say, the cylinders were exchangeable with NMS (and maybe JMS) and few were available outside this network. These also leaked out to industrial use such as in the cottage wielding industry. Attempts to colour code them and restrict the leakage of cylinders to the industrial users was yet to yield results.

Documentation and procedures for running an oxygen system are insufficient

Interviews with health workers across the facilities we visited suggested that documentation of medical oxygen use was haphazard. We found that medical oxygen use was not provided for in the current health information systems architecture of Uganda. Documenting medical oxygen consumption trends was not provided for in routinely collected data using the Ministry of Health - health management information system (HMIS) at health facility level. Our findings revealed that consumption patterns were rarely documented at the frontline level of service delivery which negatively impacted the data available to inform the planning and implementation of the entire medical oxygen supply chain. There were no paper-based or digital platforms that allowed for capturing data on medical oxygen demand and supply at routine points of care.

Within health facilities in Uganda, there appeared to be no formal standardized medical oxygen information management systems for unit operations like procurement, ordering, storage, intra-facility distribution and use in patients. We found multiple regimes for the management of medical oxygen supply chains at different facilities. The cadres of health workers involved in the medical oxygen supply chain management were diverse. Overall, we found that nurses were the most frequently cited cadre regarding medical oxygen decision making at the bottom stream end of the supply chain. Often, nurses managed the requisition for the commodity at the point of service delivery. However, most requisitions for oxygen were made largely out of medical emergencies on the various wards such as NICUs, ICUs or labour suites rather through systematic procurement planning.

"The standard requisitioning is usually done by the nurse who puts in a requisition to the store keeper or such other staff. But most of these orders come in as emergency orders. They are not routine orders. But our PSA plant has been down for some time now. So, we have actually been placing orders to National Medical Stores." Facility in-charge.

Even at the level of tertiary hospitals we found vast variations in the availability of specialized personnel for managing medical oxygen supply chains. At Mbarara RRH in South Western Uganda, we found that a qualified biomedical engineer was on the staff. The biomedical engineer oversaw requisitions for medical oxygen and was instrumental in running the two PSA plants at Mbarara RRH. However, this was the exception rather than the rule in the rest of the tertiary hospitals we visited. At Fort Portal RRH in mid-western Uganda, there was no qualified biomedical engineer or trained plant operator. Staff who managed PSA plants were in their roles on an ad-hoc basis and didn't have specialized training for the roles in which

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they were deployed. At the secondary level of service delivery, such as at general hospitals, the level of specialization of personnel for medical oxygen was even lower.

Our qualitative interviews revealed the diverse cadres of specialized staff required to run and operate PSA plants one of the many functions of managing medical oxygen supply chains.

"*With regard to the required staff responsible for running an oxygen plant, you need plant operators, you need a plant maintenance team, you need an estates and you need a mechanical engineer. So the staff you need includes a civil engineer, an electrical engineer, a plumbing technician. You need a monitoring team to ensure that the quality of oxygen produced meets the standards.*" Plant Operator, National Medical Stores.

In terms of processes or procedures for requisitioning for medical oxygen, we found that there were wide variations in practices in our sample of facilities. Overall, it is a nurse who places orders for the commodity with a 'storeman' although the term to describe such personnel may vary across facilities. We found that even in facilities which have on-site PSA plants, the process of requisition still involved a nurse or clinician placing an order with some personnel in the facility managing medicines and commodities who either did not a proper job description or did not have the requisite knowledge, skills and capacity building opportunities or both.

Additional methods information

This case study is based on empirical data collected from 10 key informant interviews – four female and six male - of purposively selected participants, review of extracts of publications in the national media dailies, and review of reports of four consultative workshops held by the National Medical Oxygen Coordinating Task Force between January and June 2024. The participants in the interviews were selected for maximum variation to enable the study to explore and dig deeper into different views of the realities of the medical oxygen supply chain in Uganda as shown below.

Representatives from health sector partners engaged in supporting the Ministry of Health on the National Implementation Plan for Medical Oxygen Scale-up
Non-state practitioners in the medical oxygen supply chain ecosystem
Activist from a Civil Society Organization engaged on health advocacy
Actors in the public sector on the medical oxygen supply chain ecosystem
Ministry of Health officials
Practicing health worker at one of the study health facilities

Table 2: Key informant interview participants

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ABOUT THE COMMISSION

Announced in September 2022, *The Lancet Global Health* Commission on Medical Oxygen Security provides a thorough exploration of medical oxygen coverage gaps, with recommendations to ensure that no patient dies for lack of access to this essential medicine, including during public health emergencies like COVID-19.

The Commission was led by 18 Commissioners - multi-disciplinary academics with clinical, economic, engineering, epidemiological, and public policy expertise - representing all regions of the world. Forty Advisors representing United Nations and global health agencies, donors, academic institutions, and non-governmental organizations provided guidance. A large global network of Oxygen Access Collaborators provided constant input to the Commission and included representatives from industry and Ministries of Health. Special consultations were conducted with patients, caregivers, and clinicians to ensure that their voices and experiences shaped the Commission's recommendations.

An Executive Committee coordinated the work of the Commission and included representatives from **Makerere University**, Uganda; **International Centre for Diarrheal Disease Research** (icddr,b), Bangladesh; **Murdoch Children's Research Institute** (MCRI), Australia; **Karolinska Institutet**, Sweden; and **Every Breath Counts Coalition**, USA.

You can find the Commission report here and the advocacy package here, including:

- ***Report with Comments***
- ***Policy Brief (English, French, Spanish, Arabic, Chinese, and Russian)***
- ***Spotlight Brief: Access to Medical Oxygen Scorecard ($ATMO_2S$)***
- ***Spotlight Brief: Patient and Caregiver Testimonials***
- ***Spotlight Brief: 10 Oxygen Coverage Indicators***
- ***Spotlight Brief: 20 Priority Areas for Oxygen Innovation***
- ***Country Case Studies***

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