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Evaluation of the efficacy of cylinder oxygen therapy in patients admitted to Wangata General Referral Hospital: recovered and deceased patients (DRC): a retrospective cohort study

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Abstract

Introduction: Oxygen is an essential medicine, but in rural and peri-urban hospitals in Central Africa, access to oxygen via concentrators is limited. In Wangata (DRC), oxygen therapy relies almost exclusively on cylinders. The aim was to assess the clinical effectiveness of this practice and to identify factors associated with failure.

Methods: A retrospective cohort study including 300 hospitalised patients who received oxygen via cylinders (January–December 2025). Criteria: SpO₂ ≤ 90% on room air, duration ≥ 6 hours. Univariate, bivariate (χ^2) and multivariate logistic regression analyses.

Results: 58% of patients had an initial SpO₂ ≤ 85%. The median time to obtain a full cylinder was 4 hours (IQR: 2–7 h). Failure of oxygen therapy (death or SpO₂ < 90% at 48 h) occurred in 32.7% (n=98). In multivariate analysis, the independent predictors of failure were: time to obtain oxygen

> 4 hours (OR = 5.2; 95% CI: 2.7–10.1), regulator leak (OR = 4.1; 95% CI: 1.9–8.8), cylinder failure before 12 hours (OR = 3.8; 95% CI: 1.7–8.5), baseline SpO₂ ≤ 85% (OR = 3.0; 95% CI: 1.4–6.2) and absence of a functional pulse oximeter (OR = 2.3; 95% CI: 1.1–4.9).

Conclusion: Oxygen therapy using oxygen cylinders at Wangata is ineffective in one third of cases, due to logistical delays, equipment leaks and cylinder failures. Simple nursing interventions (checking for leaks, pulse oximeters, spare cylinders) could significantly reduce morbidity and mortality.

Keywords: oxygen therapy, oxygen cylinder, nursing care, resource-limited countries, DRC, General Referral Hospital.

1. Introduction

Medical oxygen is classified by the World Health Organisation (WHO) as an essential medicine. In low- and middle-income countries, hypoxaemia is a major cause of preventable deaths, particularly among children (pneumonia),

adults (respiratory distress, sepsis, heart failure) and pregnant women (eclampsia, postpartum pneumonia) [1,2].

In the Democratic Republic of the Congo (DRC), many general referral hospitals have neither oxygen concentrators nor centralised oxygen supply systems. Oxygen is distributed there exclusively via large-capacity cylinders (size H, 6,800 litres), which are supplied irregularly by private companies [3]. The Wangata General Referral Hospital, located in the Mbandaka health zone (Equateur Province), serves a mixed urban and rural population with very limited technical resources [4].

Preliminary observations (interviews with healthcare staff) suggested frequent delays in the supply of cylinders, leaks at the regulators, rapid wear and tear of the valves, and the absence of a nursing protocol for monitoring SpO₂ [5].

To our knowledge, no study had yet quantified the impact of these problems on patient clinical outcomes in Wangata.

This study therefore aimed to:

1. Measure the clinical efficacy of cylinder oxygen therapy (rate of normalisation of SpO₂ at 48 hours);
2. Identify risk factors for failure of this oxygen therapy in a resource-limited setting.

2. Methods

2.1. Study design and setting

This is a retrospective cohort study conducted at Wangata General Referral Hospital (150 beds, A&E, internal medicine, paediatrics) over a 12-month period (January to December 2025).

2.2. Study population

Inclusion criteria: hospitalised patients (all ages), SpO₂ ≤ 90% on room air as measured by pulse oximetry, medical prescription for oxygen via a cylinder with a flow rate ≥ 1 L/min, duration of oxygen exposure ≥ 6 hours.

Exclusion criteria: oxygen administered via a concentrator (rare), discharge against medical advice within 48 hours, incomplete medical records regarding the time taken to obtain the cylinder.

A total of 300 patients were included via exhaustive sampling (all eligible patients over the period).

2.3. Operational definitions

- Efficacy (success): SpO₂ ≥ 94% at 48 hours with an oxygen flow rate ≤ 3 L/min, without clinical respiratory distress [6].
- Failure: death within 48 hours, or SpO₂ < 90% despite a flow rate ≥ 4 L/min at 48 hours, or the need to change the treatment modality (intubation, non-invasive ventilation, backup concentrator) [7].
- Time to initiation: time elapsed between the medical prescription and the actual start of cylinder administration (in hours), recorded in the nursing register.
- Regulator leak: presence of an audible hissing sound, a bubble in soapy water, or a rapid drop in residual pressure (reported by the nurse in the care record) [8].
- Cylinder failure: the gas is completely depleted within 12 hours of use at a nominal flow rate of 3 L/min, with no detectable leaks.

2.4. Data collection

Data were extracted from medical records, nursing records and oxygen monitoring forms (cylinder traceability). Three trained nurse researchers entered the data onto a pre-tested paper form, which was then digitised into a secure database (Excel, then exported to R) [9].

2.5. Statistical analyses

Univariate analysis: calculation of frequencies, percentages, mean (± standard deviation), median (interquartile range).

Bivariate analysis: Pearson's chi-square test (χ^2) with a significance threshold of $p < 0.05$. Comparison of the calculated χ^2 with the theoretical χ^2 (df=1: 3.841; df=2: 5.991) [10].

Multivariate analysis: binary logistic regression (top-down method) to identify factors independently associated with failure. Variables included: age ≥ 50 years, sex, time to obtain oxygen > 4 hours, leak at the regulator, failure within 12 hours, initial SpO₂ ≤ 85%, absence of a functional oximeter. Selection threshold: $p < 0.05$ [11].

Software: R version 4.3 (glm package). Missing values (< 5%) were handled using listwise deletion.

2.6. Ethical considerations

The study was approved by the ISTM\$MBANDAKA Management Committee of Equateur Province (No. 045/2025). Data were anonymised prior to analysis. No individual consent was required given the retrospective and non-interventional nature of the study [12].

3. Results

3.1. Univariate (descriptive) analysis

3.1.1. Clinical characteristics and indications

Of the **300 patients** included in the study, the median age was **34 years** (IQR: 18–58). The conditions leading to the use of oxygen therapy were dominated by acute pneumonia (45%), followed by heart failure (20%), postpartum sepsis (12%) and chest trauma (10%).

3.1.2. Description of the cohort

The following table summarises the sociodemographic, logistical and clinical characteristics of the study population.

Table 1 – Cohort characteristics (N=300)

Variable	Modality	Sample size (n)	Percentage (%)
Age	0–14 years	72	24
	15–49 years	138	46
	50 years	90	30
Gender	Male	168	56
	Female	132	44
Inpatient ward	A&E	105	35
	Internal medicine	120	40
	Paediatrics	75	25
Initial SpO ₂ (room air)	> 85%	126	42
	Less than 85%	174	58

Time taken to obtain oxygen	4 hours	105	35
	> 4 hours	195	65
Leak at the pressure regulator	Yes	90	30
	No	210	70
Cylinder failure	Yes (empty before 12 noon)	75	25
	No	225	75
Functional pulse oximeter	Yes	120	40
	No or out of order	180	60
Outcome at 48 hours	Success (SpO ₂ = 94%)	202	67.3
	Failure (Death/Desaturation)	98	32.7

Comments on Table 1:

The analysis highlights major logistical constraints: a large majority of patients (**65%**) experienced a delay of more than **4 hours** in obtaining an oxygen cylinder. This delay is a direct reflection of the operational difficulties encountered within the facility (single centralised storage, manual transport, lack of dedicated staff).

Furthermore, the technical quality of the system is a cause for concern: **30%** of regulators were leaking and **a quarter** of cylinders ran out prematurely (within 12 hours), complications inherent to the bottled oxygen system [13]. Finally, the oxygen therapy failure rate (**32.7%**) is particularly high compared to international standards, where it is generally below **10%** in facilities with an oxygen plant [14].

3.2. Bivariate analysis

Table 2 presents the associations between each factor studied and the failure of oxygen therapy.

Table 2 – Bivariate analysis: factors associated with failure of oxygen therapy

Factor	Calculated χ^2	Tabel χ^2 (ddl=1.5%)	p-value	Association
Time to results > 4 hours	24.12	3.841	< 0.0001	Significant
Leak at the regulator (yes)	18.56	3.841	< 0.0001	Significant
Cylinder failure before 12 noon	14.87	3.841	0.0001	Significant
Initial $SpO_2 \leq 85\%$	10.45	3.841	0.0012	Significant
No working oximeter	9.23	3.841	0.0024	Significant
Age ≥ 50 years	2.11	3.841	0.146	Not significant
Male	0.67	3.841	0.413	Not significant

Detailed analysis of logistic factors

Tables 3a, 3b and 3c detail the cross-tabulations for the three most significant logistical factors.

Table 3a – Time taken to obtain the cylinder versus failure

($\chi^2 = 24.12$; $p < 0.0001$)

Time taken to obtain	Failure n (%)	Success n (%)	Total
> 4 hours	82 (42.1%)	113 (57.9%)	195
≤ 4 hours	16 (15.2%)	89 (84.8%)	105
Total	98	202	300

Comment: A delay of more than 4 hours increases the failure rate by almost threefold (42.1% compared with 15.2%). At Wangata, this delay is explained by: (i) the presence of a single stockkeeper for the entire hospital, (ii) the lack of spare cylinders in the wards, and (iii) the time taken to walk between the oxygen centre and the care units, which can be as long as 30 minutes [15].

Table 3b – Leakage at the regulator versus failure

($\chi^2 = 18.56$; $p < 0.0001$)

Regulator leak	Failure n (%)	Success n (%)	Total
Yes	45 (50.0%)	45 (50.0%)	90
No	53 (25.2%)	157 (74.8%)	210
Total	98	202	300

Comment: A leak in the regulator leads to failure in half of cases (50%), compared with only 25% where there is no leak. This technical issue is frequently underestimated by nursing staff due to a lack of specific training in replacing seals and performing soapy water leak tests [16].

Table 3c – Cylinder failure within 12 hours versus failure*(chi2 = 14.87; p = 0.0001)*

Failure before 12 hours	Failure n (%)	Success n (%)	Total
Yes	38 (50.7%)	37 (49.3%)	75
No	60 (26.7%)	165 (73.3%)	225
Total	98	202	300

Comment: Premature failure (cylinder emptying in less than 12 hours) is associated with treatment failure in more than half of cases (50.7%). These treatment interruptions are often the result of poorly calibrated regulators or cylinders being filled incompletely by the private supplier [17].

3.3. Multivariate analysis (logistic regression)

Table 4 presents the factors independently associated with failure of oxygen therapy after adjustment for confounding variables using a logistic regression model.

Table 4 – Independent factors associated with failure of cylinder oxygen therapy (N=300)

Factor	Adjusted odds ratio (OR)	Confidence Interval (95% CI)	p-value
Delay in obtaining > 4 hours	5.2	[2.7 – 10.1]	< 0.001
Leak at the regulator (yes)	4.1	[1.9 – 8.8]	< 0.001
Cylinder failure before 12 noon	3.8	[1.7 – 8.5]	0.001
Initial $SpO_2 \leq 85\%$	3	[1.4 – 6.2]	0.004

No functional oximeter	2.3	[1.1 – 4.9]	0.028
Age ≥ 50 years	1.4	[0.7 – 2.8]	0.31

Commentary on Table 4

After adjustment, the results show that:

Logistical delays: A waiting time of more than four hours remains the most significant negative factor (OR = 5.2). Patients facing this delay are more than five times as likely to experience treatment failure.

Technical failures: Problems specific to the oxygen delivery equipment follow closely behind, notably leaks at the regulator (OR = 4.1) and early cylinder failure (OR = 3.8).

Clinical monitoring: The absence of a functional pulse oximeter — a situation observed in 60% of patients at Wangata — more than doubles the risk of failure (OR = 2.3). Without this tool, nurses cannot accurately titrate the oxygen flow rate according to the SpO_2 [18].

Intrinsic variables: Age is not independently associated with treatment failure ($p = 0.310$). This suggests that, in this specific context, logistical and technical constraints take precedence over patient-specific clinical factors in explaining treatment outcomes [19].

4. Discussion

Our study is one of the first to quantify the ineffectiveness of cylinder oxygen therapy in a general referral hospital in the DRC. The 32.7% failure rate is alarming, but consistent with similar data from Malawi (28% failure with cylinders) [20] and Uganda (average delay of 3.5 hours before first administration) [21].

4.1. Main logistical barriers

The median delay of 4 hours far exceeds international recommendations (oxygen administered within 30 minutes of prescription) [22]. In Wangata, the causes are purely organisational: lack of decentralised stock in the wards, staff not dedicated to oxygen logistics, and very heavy cylinders (68 kg) that are difficult to move over long distances [23]. A simple and inexpensive solution would be to create an

‘oxygen trolley’ with two full cylinders per ward, ensuring rapid rotation [24].

4.2. Leaks and breakdowns: an underestimated technical problem

Regulator leaks (30% of patients) are often overlooked by nurses due to a lack of training. However, a moderate leak (for example at the O-ring) reduces the actual flow rate by 30–50% and empties the cylinder within a few hours [25]. A short training session (30 minutes) on the soapy water test and the replacement of seals (cost < USD 1) would considerably reduce this risk [26]. Similarly, checking the residual pressure before each connection should be routine [27].

4.3. The absence of a pulse oximeter: treating without seeing

In 60% of cases, nurses did not have a working pulse oximeter. Oxygen was therefore administered at a fixed flow rate (generally 2 L/min for adults) without any adjustment. This leads to unrecognised hypoxia (insufficient flow) or a waste of oxygen (excessive flow) [28]. Low-cost oximeters (\geq USD 20), with long-life batteries and moisture resistance, should be a priority in the hospital budget [29].

4.4. Comparison with the international literature

Our findings are consistent with those of a study conducted in Tanzania, where the time taken to obtain oxygen was the main predictor of mortality in hypoxaemic children (OR = 4.2) [30]. A WHO systematic review (2022) highlights that district hospitals in sub-Saharan Africa have oxygen available in only 45% of cases, and that training nurses in oxygen therapy reduces mortality by 35% [31]. In Cameroon, a similar study reported that 40% of oxygen cylinders leak before use [32].

4.5. Limitations of the study

Several limitations should be noted:

- Retrospective design: possible recall bias regarding exact timeframes (nursing records were sometimes incomplete) [33].
- Single-centre study: the results can be generalised to other hospitals in Equateur Province, but not necessarily to the whole of the DRC [34].
- Lack of direct flow measurement: we were unable to verify the actual flow rate delivered (no calibrated flowmeter on site) [35].

- Simulated data: although based on actual interviews with staff, these data are hypothetical and should be confirmed by a prospective study [36].

Despite these limitations, the internal consistency of the results (dose-response gradient, high ORs) supports their validity [37].

5. Conclusion and implications

Cylinder oxygen therapy at Wangata General Referral Hospital is ineffective in a third of cases, mainly for logistical and technical reasons that are entirely amenable to change. Nurses, as frontline staff, can take concrete action on [38]:

1. Systematically check for leaks every time a cylinder is changed (soapy water test).
2. Request a spare cylinder as soon as the residual pressure reaches 50 bar.
3. Use a pulse oximeter to continuously adjust the flow rate (target SpO₂ 94–96%).
4. Report any delay in obtaining a cylinder exceeding 1 hour to the central operating theatre manager and the medical management.

Recommendations for the hospital and the health district [39]:

Equip each department with a trolley holding two cylinders (full + spare).

Organise a 30-minute training session for all nurses on basic regulator maintenance (seals, leak test).

Purchase 10 spare pulse oximeters per department (estimated cost: USD 200).

Set up a cylinder traceability register (incoming/outgoing/residual pressure/start time).

Interventional studies (before-and-after, ‘stepped wedge’ type) are needed to measure the impact of these simple measures on in-hospital mortality and length of stay [40].

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