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ABSTRACT
Objective Global medical oxygen security is limited by knowledge gaps in hypoxaemia burden and oxygen access in low-income and middle-income countries. We examined the prevalence and phenotypic trajectories of hypoxaemia among hospitalised adults in Kenya, with a focus on chronic hypoxaemia.

Setting National tertiary referral hospital in Eldoret, Kenya between September 2019 and April 2022.

Participants Adults (age ≥18 years) admitted to general medicine wards.

Primary and secondary outcome measures Our primary outcome was proportion of patients who were hypoxaemic (oxygen saturation, SpO2 ≤88%) on admission. Secondary outcomes were proportion of patients with hypoxaemia on admission who had hypoxaemia resolution, hospital discharge, transfer, or death among those with unresolved hypoxaemia or chronic hypoxaemia. Patients remaining hypoxaemic for ≤3 days after admission were enrolled into an additional cohort to determine chronic hypoxaemia. Chronic hypoxaemia was defined as an SpO2 ≤88% at either 1-month post-discharge follow-up or, for patients who died prior to follow-up, a documented SpO2 ≤88% during a previous hospital discharge or outpatient visit within the last 6 months.

Results We screened 4104 patients (48.5% female, mean age 49.4±19.4 years), of whom 23.8% were hypoxaemic on admission. Hypoxaemic patients were significantly older and more predominantly female than normoxaemic patients. Among those hypoxaemic on admission, 33.9% had resolution of their hypoxaemia as inpatients, 55.6% had unresolved hypoxaemia (31.0% died before hospital discharge, 13.3% were alive on discharge and 11.4% were transferred) and 10.4% were lost to follow-up. The prevalence of chronic hypoxaemia was 2.1% in the total screened population, representing 8.8% of patients who were hypoxaemic on admission. Chronic hypoxaemia was determined at 1-month post-discharge among 59/86 patients and based on prior documentation among 27/86 patients.

STRENGTHS AND LIMITATIONS OF THIS STUDY
⇒ We used rigorous screening procedures to identify hypoxaemia.
⇒ We used a high-quality pulse oximeter with repeat initial assessments to ensure oxygen saturation accuracy.
⇒ We captured a large sample size of adult inpatients in a large, national referral hospital.
⇒ The study only assessed hypoxaemia at a single site and 1/10 of patients were lost to follow-up.
⇒ We lacked detailed clinical data, such as reason for admission, and were not able to ascertain mortality for all hypoxaemic patients.

Conclusion Hypoxaemia is highly prevalent among adults admitted to a general medicine ward at a national referral hospital in Kenya. Nearly 1 in 11 patients who are hypoxaemic on admission are chronically hypoxaemic.

INTRODUCTION
Hypoxaemic respiratory failure is a major cause of morbidity and mortality worldwide. Acute hypoxaemia has been identified as an important prognostic risk factor for patients presenting to a hospital with conditions such as pneumonia, pancreatitis, pulmonary embolism or COVID-19 infection. For patients who survive these conditions, their hypoxaemia usually resolves with treatment of the underlying aetiology. However, for many patients with chronic cardiopulmonary disease, hypoxaemia persists beyond acute illness and is considered chronic hypoxaemia. Chronic hypoxaemia is also associated with significant mortality and long-term oxygen therapy reduces this risk. However, oxygen is not widely and consistently available in many low-income and middle-income countries, despite it being listed as a WHO Essential
Medicine. COVID-19 has made the need for expanded oxygen access even more urgent and imperative.

There are major data gaps in oxygen research including data on the prevalence of hypoxaemia among hospitalised adults, their health outcomes and the availability of oxygen therapy for patients with chronic hypoxaemia. Many of the existing studies across the African continent focus on children and/or neonates, and there are virtually no data on chronic hypoxaemia in adults.

To address this knowledge gap, we conducted a prospective cohort study to assess rates of both acute and chronic hypoxaemia among adults admitted to the general medicine wards at Moi Teaching and Referral Hospital (MTRH), a public tertiary hospital in western Kenya. Through a rigorous screening protocol, we evaluated the prevalence of hypoxaemia on admission in this population, and assessed phenotypes of hypoxaemia trajectory, with a specific focus on chronic hypoxaemia. Thus, we also enrolled patients with persistent hypoxaemia for ≥5 days into an additional cohort to assess rates of chronic hypoxaemia.

METHODS

Study design and participants

This prospective, observational cohort study was conducted at MTRH, the second largest national referral hospital in Kenya with a catchment population of 24 million. MTRH consists of several different wards, such as general medicine, surgery, paediatrics, obstetrics and gynecology (OB/GYN) and mental health wards, as well as a mixed medical-surgical intensive care unit and a cardiac critical care unit. The general medicine wards are among the largest in the hospital, responsible for caring for adult patients with a wide range of non-surgical issues. We systematically screened all adult (age ≥18 years) patients admitted to the general medicine wards on hospital day 1 (within 24 hours of admission) for hypoxaemia. Age and sex were abstracted from admission logs and were confirmed with the patient. Screening occurred between September 2019 and December 2021 on Monday to Friday mornings for all patients admitted Sunday to Thursday, with pauses in screening due to the COVID-19 pandemic. Since the COVID-19 pandemic began about 7 months into our study when COVID-19 positivity rates in the community were low (<5%).

Hypoxaemia was defined as oxygen saturation (SpO2) ≤88% on room air or receiving oxygen supplementation and nonetheless with an SpO2≤88% (see online supplemental file S1 for further details). SpO2 was assessed using a Masimo Rad-5v handheld pulse oximeter with a minimum of two readings on separate digits. The Masimo pulse oximeter was chosen given that it meets the international Organisation for Standardisation criteria for accuracy and studies showing a high degree of accuracy, sensitivity and specificity.

Hypoxaemic patients were followed with daily SpO2 assessments until one of the following outcomes could be ascertained: resolution of hypoxaemia, discharge from the hospital, transfer to another unit or hospital, death among those with unresolved hypoxaemia and/or chronic hypoxaemia. Age and sex were recorded for all screened patients. Patients who remained hypoxaemic for more than 3 days after admission were approached for enrollment into a Chronic Hypoxemia Among Kenyan Adults (CHAKA) cohort to follow patients suspected of being chronically hypoxaemic. Participants who consented to the study were followed through discharge from the hospital with daily SpO2 assessments and asked to return for a follow-up visit at least 1-month post-discharge to have their SpO2 reassessed. In addition, information on oxygen use on admission, home oxygen use and whether oxygen was prescribed and obtained at discharge, were collected for patients suspected of being chronically hypoxaemic. Data collection occurred throughout the screening period and extended to April 2022.

Trained research assistants used structured paper forms to collect participant screening data, which included admission date, age, sex and daily SpO2 assessments. Deidentified data were entered into Microsoft Excel for data management and stored on secure servers hosted by Duke University. For patients enrolled in CHAKA, additional data on home oxygen use, oxygen prescription and follow-up SpO2 were collected and managed using REDCap electronic data capture tools hosted at Duke University.

Written informed consent was obtained for participants enrolled in the CHAKA cohort. The study was also supported by the Academic Model Providing Access to Healthcare which helped provide study staff and procurement support.

Outcomes

All patients with an SpO2 >88% on initial assessment were considered normoxaemic. The decision to use an SpO2 cut-off of ≤88% was made based on its correlation to an arterial partial pressure of oxygen of about 55 mm Hg and its use as a criterion in many countries for home oxygen prescription. We also took into consideration that MTRH is located at approximately 2100 m above sea level and that an SpO2 of 88% would more reliably capture hypoxaemia from mechanisms other than altitude.

Among patients who were hypoxaemic on admission, outcome definitions are as follows: (1) hypoxaemia resolution: SpO2 improved ≥89% on room air while inpatient; (2) unresolved hypoxaemia: remained hypoxaemia throughout their hospitalisation; mortality was assessed in this group; (3) transferred: moved to a different ward within MTRH (eg, critical care unit) or to another hospital while still hypoxaemic; (4) unknown: either discharged home before study team reassessment of SpO2 or were lost to follow-up; (5) chronic hypoxaemia: among
patients enrolled in the CHAKA cohort, either survived to discharge and were still hypoxaemic at 1-month post-discharge follow-up or if hypoxaemic and died before follow-up, had a documented SpO2≤88% in their medical charts on prior hospital discharge or outpatient visit in the previous 6 months.

**Statistical analysis**

Based on MTRH data from July 2017 and June 2018, we expected approximately 7000 medicine admissions per annum. We did not calculate a sample size a priori, but estimated numbers of patients who would meet eligibility criteria and would be chronically hypoxaemic to assess feasibility of enrolling patients into the CHAKA cohort. We assumed 7% of patients would not meet eligibility criteria due to age as MTRH adult wards admit patients 15 years and older. Thus, we anticipated screening at least 5400 participants over a 12-month study period for the cross-sectional portion of our study. If we assume a 5% prevalence of chronic hypoxaemia and a screening sample of 5400 patients, we estimated 270 patients would be chronically hypoxaemic.

We used standard summary statistics to describe the cohort. Continuous variables were summarised using the mean, SD, median with 25th and 75th percentiles (Q1, Q3), and ranges dependent on normality, and compared using a t-test or Wilcoxon rank-sum test; categorical variables were summarised using counts and percentages of non-missing data and compared using a χ² or Fisher’s exact test. To assess whether age, sex and the interaction between the two were associated with inpatient mortality, we used a multivariable logistic regression model for the cohort of patients who were hypoxaemic on admission with a known vital status outcome at hospital discharge. Additionally, to assess whether age, sex and the interaction between the two were associated with chronic hypoxaemia, we used a multivariable logistic regression model between those who either had clear resolution of hypoxaemia while inpatient or were determined to be chronically hypoxaemic. Univariable analyses were also assessed to determine if there were differences in demographics and outcomes between the pre-COVID-19 era (115 days between September 2019 and 12 March 2020) and the intra-COVID-19 era (184 days between August 2020 and December 2021). ORs and 95% CIs are reported. Data were analysed using SAS software V.9.4 (SAS Institute). A p<0.05 was considered statistically significant.

**Patient and public involvement**

We did not involve patients or the public in the research design or analysis due to the subject matter and acute illness. They were not invited to contribute to design, analysis nor manuscript review. However, we did include Kenyan clinicians and research staff in the design of the study, study protocols, analysis and manuscript review.

**RESULTS**

The study population included 4104 patients (48.5% female) screened at MTRH during the study period, with a mean age of 49.4±19.4 years. Among these, 975 (23.8%) were hypoxaemic on admission (figure 1), 331 (33.9% of hypoxaemic on admission) patients had resolution of their hypoxaemia while inpatient, and 543 (55.7% of hypoxaemic on admission) did not resolve. Among those patients with unresolved hypoxaemia, 302 (31.0% of hypoxaemic on admission) patients died before hospital discharge. Additionally, 111 (11.4% of hypoxaemic on admission) patients were transferred to a critical care unit, COVID ward, another ward in MTRH, or an outside hospital or hospice facility. Final oxygen assessments or vital status could not be assessed for 101 (10.4% of hypoxaemic on admission) patients who were hypoxaemic on admission since they were either discharged home before SpO2 reassessment (N=71), declined consent for further follow-up (N=12) or were lost to follow-up (N=18).

There were 130 (13.3% of hypoxaemic on admission) patients whose hypoxaemia did not resolve during their admission, but were alive at hospital discharge and consented to 1-month follow-up via the CHAKA cohort. Among these, 101 patients (10.4% of hypoxaemic on admission) were alive at follow-up, 24 patients (2.5% of hypoxaemic on admission) died as an outpatient before follow-up, and 5 (0.5% of hypoxaemic on admission patients) were lost to follow-up as an outpatient.

**Pre-COVID-19 versus intra-COVID-19 pandemic**

There was no significant difference in the proportion of patients who were hypoxaemic on admission by COVID-19 era of screening (pre-COVID-19 vs intra-COVID-19) in univariable analysis (p=0.16). There was also no difference in the mean age or proportion of females by era of screening (online supplemental file S2).

**Sex and age**

Patients who were hypoxaemic on admission were significantly older (mean age 57.6±19.9 vs 46.9±18.6, p<0.001) and more predominantly female (54.1% vs 46.8%, p<0.001) compared with those who were normoxaemic on admission (table 1).

Rates of resolution of hypoxaemia were similar between females and males (35.2% vs 32.6%) as were rates of death during hospitalisation (30.2% vs 31.9%) (table 2). The mean age of hypoxaemic patients transferred to a critical care unit was 47.9±20.7, and there were no differences in sex among those transferred to a critical care unit (44% male vs 55.6% female, p=0.34).

The interaction between age and sex was not significant in a multivariable logistic regression model assessing the associations between age, sex and their interaction with inpatient mortality among patients who were hypoxaemic on admission and had a known vital status at hospital discharge (N=502). Additionally, neither sex (OR 0.85, 95% CI 0.59 to 1.23, female vs male) nor age (OR 0.91, 95% CI 0.83 to 1.005 per 10-year increase) was statistically significant.
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Figure 1  Screening outcomes. *Unknown includes: Discharged home prior to follow-up (N=71), lost to follow-up inpatient (N=18), Declined consent for follow-up in CHAKA (N=12). †Transferred to critical care unit (N=45), COVID-19 ward (N=49), another MTRH ward (N=13) or outside hospital or hospice (N=4). ‡These patients were determined to be chronically hypoxaemic based on an SpO2<88% at prior hospital discharge or outpatient visit. CHAKA, Chronic Hypoxemia Among Kenyan Adults; MTRH, Moi Teaching and Referral Hospital; SpO2, oxygen saturation.

Chronic hypoxaemia

We followed 130 patients who consented to CHAKA through 1-month posthospital discharge, 59 (45.4%) of whom were confirmed to be chronically hypoxaemic at follow-up. This represents 1.4% of the total screened population and 6.1% of the hypoxaemic-on-admission population. An additional 33 patients consented to participation in the CHAKA cohort but died as inpatients. Within the CHAKA cohort, 86 patients were confirmed to be chronically hypoxaemic, 59 (68.6%) of whom were confirmed based on an SpO2<88% at 1-month post-discharge and 27 (31.4%) of whom were confirmed based on chart review showing a documented SpO2<88%.

Table 1  Demographics of screened patients, by SpO2 on admission (N=4104)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (N=4104)</th>
<th>Normoxaemic on admission (N=3129)</th>
<th>Hypoxaemic on admission (N=975)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>49.4 (19.4)</td>
<td>46.9 (18.6)</td>
<td>57.6 (19.9)</td>
<td></td>
</tr>
<tr>
<td>Median (Q1, Q3)</td>
<td>47.0 (33.0, 65.0)</td>
<td>44.0 (32.0, 62.0)</td>
<td>59.0 (41.0, 73.0)</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>18.0–103.0</td>
<td>18.0–100.0</td>
<td>18.0–103.0</td>
<td></td>
</tr>
<tr>
<td>Sex, N (%)</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>Female</td>
<td>1990 (48.5)</td>
<td>1463 (46.8)</td>
<td>527 (54.1)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2114 (51.5)</td>
<td>1666 (53.2)</td>
<td>448 (45.9)</td>
<td></td>
</tr>
<tr>
<td>COVID Era, N (%)</td>
<td></td>
<td></td>
<td></td>
<td>0.17†</td>
</tr>
<tr>
<td>Pre-COVID-19</td>
<td>1871 (45.6)</td>
<td>1445 (46.2)</td>
<td>426 (43.7)</td>
<td></td>
</tr>
<tr>
<td>Intra-COVID-19</td>
<td>2233 (54.4)</td>
<td>1684 (53.8)</td>
<td>549 (56.3)</td>
<td></td>
</tr>
</tbody>
</table>

*Wilcoxon rank sum.
†χ².
SpO2, oxygen saturation.
at prior hospital discharge or outpatient visit within the last 6 months (online supplemental file S4). These 86 patients represent 2.1% of the total screened population and 8.8% of the hypoxaemic-on-admission population. The prevalence of chronic hypoxaemia among the total screened population was 2.7% among females and 1.6% among males, and the prevalence among the subset of the population hypoxaemic on admission was 10.1% among females and 7.4% among males (table 3).

The mean age of female patients with chronic hypoxaemia was 65.3±20.8, and for males was 54.1±18.4. Twenty-seven (31.4%) chronically hypoxaemic patients died by the 1-month follow-up (16.3% inpatient, 15.1% outpatient). There were no significant differences in survival by age, sex or COVID-19 era among those with chronic hypoxaemia (online supplemental file S5).

The interaction between age and sex was not significant in a multivariable logistic regression model assessing the associations between age, sex and the interaction between age and sex with the outcome of chronic hypoxaemia (N=86) among patients with known final hypoxaemia status (N=417). Additionally, neither sex (OR 1.21, 95% CI 0.95 to 1.21, per 10-year increase) was significantly associated with chronic hypoxaemia status (online supplemental file S3).

**DISCUSSION**

This study helps fill a critical knowledge gap on the prevalence of hypoxaemia, hypoxaemia trajectory phenotypes and chronic hypoxaemia among hospitalised adults in Kenya. Nearly a quarter of patients admitted to the medicine wards at a national referral hospital in Kenya were hypoxaemic on admission. Of those, nearly one-third died during their hospitalisation, while one-third had resolution of their hypoxaemia during their hospitalisation. An additional one-fifth were transferred to other units or outside hospitals and nearly one-quarter were discharged home alive but still hypoxaemic. Nearly 1 in 11 patients who were hypoxaemic on admission were chronically hypoxaemic.

Our findings on the prevalence of hypoxaemia among adult medicine ward patients adds to existing literature on prevalence of hypoxaemia in various populations across sub-Saharan Africa. A study of all inpatients age 15

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Prevalence of chronic hypoxaemia, by sex (N=86)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
<td>Total</td>
</tr>
<tr>
<td>N (%)</td>
<td>86 (100)</td>
</tr>
<tr>
<td>% hypoxaemic on admission (n=975)</td>
<td>8.8</td>
</tr>
<tr>
<td>% screened (n=4104)</td>
<td>2.1</td>
</tr>
<tr>
<td>Age, years; mean (SD)</td>
<td>61.0 (20.5)</td>
</tr>
<tr>
<td>Outcome, N (%)</td>
<td></td>
</tr>
<tr>
<td>Alive at follow-up</td>
<td>59 (68.6)</td>
</tr>
<tr>
<td>Died</td>
<td>27 (31.4)</td>
</tr>
<tr>
<td>Inpatient</td>
<td>14 (16.3)</td>
</tr>
<tr>
<td>Outpatient</td>
<td>13 (15.1)</td>
</tr>
</tbody>
</table>
years and older in Rwanda found a prevalence of hypoxaemia of 12%; a study of all inpatients age 18 years and older in Zambia found a prevalence of 9.2%; and a study of adult medical inpatients in Malawi found a prevalence of 9%. These rates are in contrast to prevalence rates reported in a study in Great Britain which found 2% of inpatients age 16 or older had an SpO2≤88%. The mortality rate among patients with unresolved hypoxaemia in our study of 31% is also higher than the adult inpatient mortality rate reported in a prior study at MTRH of 22% as well as the mortality rate reported in the Great Britain study of approximately 26%.

However, this mortality rate is similar to other studies of hypoxaemia in Rwanda, Malawi and Zambia of 30.8%–57.4%. This comparison is limited by our lack of mortality data for patients who were hypoxaemic on admission but whose hypoxaemia resolved. Patients with hypoxaemia on admission were unsurprisingly older than normoxaemic patients, given data showing that ‘normal’ SpO2 reduces with age and is slightly lower in women than men. However, their average age was 38 years highlighting the burden of hypoxaemia on a relatively young population. This was analogous to the study in Zambia by Foran et al where the average age of hypoxaemic adults was 47 years. Interestingly, younger patients who were hypoxaemic on admission in our study did not have a significantly lower risk of inpatient mortality as compared older patients. While we may be underpowered to detect a difference, we feel it is a result which warrants further investigation into the underlying aetiologies of hypoxaemia in this population, as well as the availability and utilisation of treatments for those aetiologies. Furthermore, given that <5% of patients with hypoxaemia on admission received critical care services, further studies to assess the impact of expansion of resources and services for hypoxaemic respiratory failure such as high-flow oxygen devices, ventilators and critical care beds, are also needed.

While screening for hypoxaemia overlapped with the COVID-19 pandemic, we specifically did not screen during periods where COVID-19 positivity rates were greater than approximately 5% in the community. Therefore, we cannot make any assessments of how the prevalence of hypoxaemia and various phenotypes of hypoxaemia trajectory did or did not change due to COVID-19. Rather, the lack of difference in rates of hypoxaemia as well as age and sex between pre-COVID-19 and intra-COVID-19, supports that these data represent a reasonable estimate of the burden of hypoxaemia on inpatients during non-pandemic times.

Limitations of this study include that it only assessed hypoxaemia at a single site, lower numbers of admissions due to disruption in general hospital services during surges in the COVID-19 pandemic, the proportion of patients with unknown outcomes, the lack of detailed clinical data, such as reason for admission, and the potential for having missed assessing patients who died within 24 hours of admission. All reasonable efforts were made to track patients and their paper charts, however, COVID-19 waves complicated patient enrollment and follow-up and increased the number of unknown outcomes during this time. Also, while COVID-19 impacted overall admission rates and may have affected our prevalence estimate, we found that our rates of hypoxaemia on admission and chronic hypoxaemia did not differ significantly between the pre-COVID-19 and intra-COVID-19 eras. It is difficult to discern whether patients who died before hospital discharge or follow-up but did not have a prior documented SpO2 were chronically hypoxaemic. However, assuming that the distribution of outcomes among patients with unknown final hypoxaemia outcomes is similar to the rest of the cohort, our estimate of chronic hypoxaemia in this population is likely conservative. Furthermore, the lack of clinical information such as comorbidities, diagnosis and mortality among patients whose hypoxaemia resolved limits on our understanding of the nature of hypoxaemia and its impact in this population and should be evaluated in future studies.

We chose to use a cut-off of an SpO2≤88% to define hypoxaemia. We recognise there are strong arguments to be made for using a higher cut-off of ≤90% based on the WHO for medical emergency assessment and treatment guidelines, as well as childhood pneumonia guidelines, and data showing pulse oximetry is less accurate in patients with higher skin melanin content. This decision may have led to an underestimate of chronic hypoxaemia in this population.

Strengths of the study include the rigorous screening procedures, the use of a high-quality pulse oximeter with repeat initial assessments to ensure SpO2 accuracy, and a large sample size drawn from a national referral hospital. Furthermore, we provide a replicable case definition for chronic hypoxaemia in resource-limited settings as well as a practical method to identify chronically hypoxaemic patients.

CONCLUSIONS

Hypoxaemia is highly prevalent in patients admitted to the medical wards of a national referral hospital in Kenya, and a high rate of inpatient mortality exists among these patients. Further characterisation of aetiologies of both acute and chronic hypoxaemia and their treatment is needed in conjunction with with implementation efforts to improve outcomes among patients with hypoxia.
Sylvia Kitur, for their hard work and dedication to data collection, follow-up and interpretation of our study findings. We also would like to thank the Moi Teaching and Referral Hospital nursing, medical and records staff for their support of and contributions to this project as well as Nancy Ochieng for her help with data collection. We also acknowledge the Duke Hubert-Yetargent Center for Global Health, the AMPATH Consortium, and the AMPATH Research Office for their support. Preliminary data from the first 505 participants from this study was presented as an abstract at the American Thoracic Society Conference in May of 2020. NN is responsible for the overall content as the guarantor.

**Contributors** NN contributed to the data curation, formal analysis, writing of the original draft, and revising and editing of the manuscript. DLK contributed to the conceptualisation, data curation, methodology, and supervision of the study and revising and editing of the manuscript. EB and SK contributed to data curation, methodology, and editing of the final manuscript. JE contributed to the methodology, formal analysis and revising and editing of the manuscript. AP and CLG contributed to the analysis and editing of the manuscript. DMM, NM, NMT, PSK, KW-K and LGG contributed to the conceptualisation, funding acquisition, methodology, supervision of the study and revising and editing of the manuscript.

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**Competing interests** None declared.

**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not applicable.

**Ethics approval** This study involves human participants and all study procedures were approved by the ethical review boards at Duke University (Pro01000397) and Moi University (IREC/2019/72). Participants gave informed consent to participate in the study before taking part.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available on reasonable request. Due to ethical restrictions data are available on request. Additional data from the ongoing Chronic Hypoxemia among Kenyan Adults (CHAKA) study may be available for researchers who meet the criteria for access to confidential data. Please contact the corresponding author (neelima.navuluri@duke.edu) with requests.

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**Author note** The research team has engaged constructively with the fifteen questions outlined as part of the BMJ reflexivity statement. They co-developed the research study, including study design, analysis and manuscript preparation. The study addresses priority research questions for the LMIC partner (DLK) who is an established researcher and is listed as the second author, as well as LMIC partners EB and SK, who have worked on several cardiopulmonary research projects in Kenya over the last decade. DLK provided mentorship to the first author (NN) who is an early-career researcher. The research team maintained an open conversation throughout data collection and analysis. All members have access to the data.

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