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Technology to improve reliable access to oxygen in Western Uganda: study protocol for a phased implementation trial in neonatal and paediatric wards

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ABSTRACT

Introduction Oxygen is an essential medicine for children and adults. The current systems for its delivery can be expensive and unreliable in settings where oxygen is most needed. FREO$_2$ Foundation Australia has developed an integrated oxygen system, driven by a mains-powered oxygen concentrator, with the ability to switch automatically between low-pressure oxygen storage device and cylinder oxygen in power interruptions. The aim of this study is to assess the clinical impact and cost-effectiveness of expanding this system to 20 community and district hospitals and level IV facilities in Western Uganda.

Methods and analysis This will be a phased implementation with preintervention and postintervention comparison of outcomes. Standardised baseline data collection and needs assessment will be conducted, followed by implementation of the FREO$_2$ Oxygen System in combination with pulse oximetry in 1–2 facilities per month over a 16-month period, with a total 23-month data collection period. The primary outcome will be the proportion of hypoxaemic children receiving oxygen pre and post oxygen system. Secondary outcomes will assess clinical, economic and technical aspects. Pre and post oxygen system primary and secondary outcomes will be compared using regression models and standard tests of significance. Useability will be quantitatively and qualitatively evaluated in terms of acceptability, feasibility and appropriateness, using standardised implementation outcome measure tools.

Ethics and dissemination Ethics approval was obtained from Mbarara University of Science and Technology (MUREC 1/7) and the University of Melbourne (2021-14489-13654-2). Outcomes will be presented to the involved facilities, and to representatives of the Ministry of Health, Uganda. Broader dissemination will include publication in peer-reviewed journals and academic conference presentations.

Trial registration number ACTRN12621000241831.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ We will evaluate the use of novel technology to overcome the oxygen access gap in resource constrained settings and add to the toolkit of available technology for affordable and sustainable oxygen access.

⇒ This expanded programme builds on previous implementation of the FREO$_2$ system in Mbarara Regional Referral Hospital, Western Uganda, and will be managed by a multidisciplinary team of clinicians, engineers and health workers.

⇒ Implementation will be phased but not randomised. Outcomes are compared within and between facilities at different time points pre and post oxygen system. This allows assessment of the influence of confounders, including time.

⇒ The programme has a strong emphasis on strengthening the use of pulse oximetry, training and standardised clinical guidelines for oxygen therapy.

INTRODUCTION

Pneumonia is the single largest infectious cause of death in children worldwide.[1] Children who are poor, malnourished and living in remote areas are most at risk and the burden placed by pneumonia on families and health systems aggravates existing inequalities.[2]

Hypoxaemia—low oxygen levels—complicates respiratory and non-respiratory illness in newborns and children, and significantly increases the risk of a child dying.[3 4] Pulse oximetry can non-invasively diagnose hypoxaemia, and has been shown to reduce mortality rates and improve measures of quality of care when implemented systematically.[5] Oxygen systems—a suite of interventions aimed at improving the diagnosis and management of hypoxaemia—is a proven intervention shown to reduce pneumonia mortality by up to 35%–50%.[6 7] Oxygen is included in WHO's essential medicines list,[8] and there is evidence that interventions aimed at detecting and treating hypoxaemia are economically competitive compared with other pneumonia interventions.[9 10]

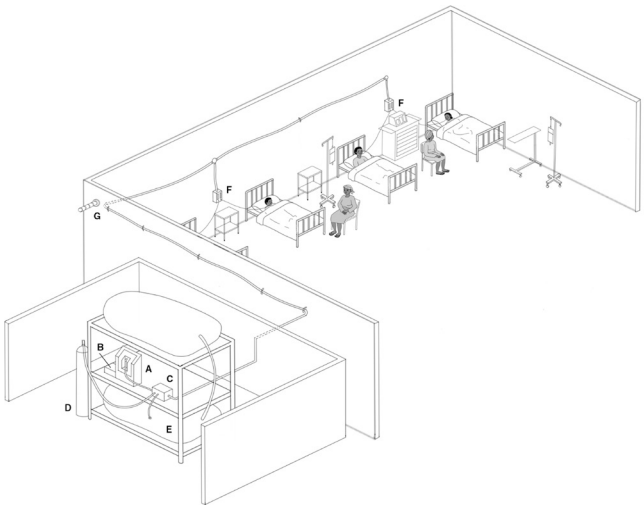

Figure 1 $FREO_2$ oxygen system, consisting of an oxygen concentrator (A), PROTECT—power conditioning system (B), Prioritiser—pneumatic switch that automatically controls oxygen source (C), back-up cylinder (D), low-pressure oxygen storage (E), patient flow-metres (F) and Stack Lamp—traffic light display that communicates the status of the system (G). image reprinted from Peake *et al*, and inspired by a similar illustration by David Woodroffe.[20]

However, the availability and use of oxygen and pulse oximetry continues to be limited globally. A survey of 231 health centres and hospitals in 12 African countries, found only 44% of facilities reporting uninterrupted oxygen access.[11] In Nigeria, while 11/12 studied facilities had some access to oxygen, the majority of this was produced by faulty concentrators and below the recommended oxygen purity.[12] In the same study, because of limitations in use of pulse oximetry, and substandard oxygen, 90% of children who had evidence of hypoxaemia did not receive appropriate oxygen therapy. Globally, there are insufficient detailed data on oxygen access and pulse oximetry to fully understand the breadth and depth of these problems.[13]

Oxygen concentrators, in appropriate settings, can improve the reliability, and reduce ongoing costs of oxygen when compared with cylinders.[14 15] However, a systematic review of electricity supply in sub-Saharan facilities found that up to 72% of facilities do not have reliable access.[16] Poor-quality grid electrical supply can damage concentrators and shorten their life span.[17] More recent programmes have trialled solar-powered systems, demonstrating cost-effectiveness[10] and mortality reductions in more rural and remote settings.[18]

As an additional tool to improve the applicability, cost and efficiency of concentrators, particularly in rural and isolated facilities, the $FREO_2$ oxygen system (figure 1) combines a robust oxygen concentrator with a low-pressure oxygen storage (LPOS) device able to store 1400 L of oxygen.[19] When the concentrator stops producing oxygen during a power cut the oxygen begins automatically flowing from the stored oxygen. Should the LPOS Store be emptied during a prolonged power cut, oxygen is automatically recruited from a high-pressure cylinder to continue supply. This control of oxygen source is achieved by a 'Prioritizer device': a pneumatic switch that can automatically switch between concentrator, LPOS and cylinder oxygen without additional intervention from health workers. A traffic light (Stack Lamp) display communicates the status of the system to nursing staff (green=concentrator oxygen, orange=LPOS oxygen, red=back up cylinder oxygen). The oxygen concentrator is connected to a PROTECT device, that conditions the mains power to meet the specific electrical requirements of the concentrator. This system has been recently field tested at the Mbarara Regional Referral Hospital in Uganda.[20]

The $FREO_2$ oxygen system is designed to require a minimum of maintenance and no direct input from the health workers (other than controlling the flow rate of oxygen to individual patients).

The aim of this study is to expand and evaluate the $FREO_2$ technology and sustainability model in 20 mid-level facilities in Western Uganda.

METHODS AND ANALYSIS

This protocol has been written in accordance with the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) statement 2013.[21]

Site selection

Health facilities will be selected based on a number of considerations: (1) oxygen availability in facilities can be improved; (2) facility oxygen needs are significant, and cannot be met sustainably and affordably with primary oxygen sources; (3) there is enthusiasm and supportive leadership within the facility for the programme; (4) geographical proximity to $FREO_2$ Uganda base and (5) are representative of the type of facilities in Western Uganda (public, private not-for-profit and private for profit).

A facility-selection questionnaire will be sent out by email to 60 facilities, within 90 min driving distance from the $FREO_2$ office (online supplemental appendix 1). Facility administrators are asked to provide information on case load, infrastructure, human resources and willingness to participate. Eligible facilities are visited, and a baseline assessment (online supplemental appendix 2), using a standardised tool is completed. The assessment collects more detailed information on admissions numbers, pneumonia burden, pre-existing oxygen supplies, access to pulse oximetry, oxygen costs, staffing and biomedical support. Selection and recruitment of facilities is unblinded and non-randomised.

Inclusion criteria and enrolment

All neonatal and paediatric (<12 years) admissions to selected health facilities will be included and screened with pulse oximetry. Information on oxygen therapy is collected for admitted children on oxygen. Hypoxaemia,

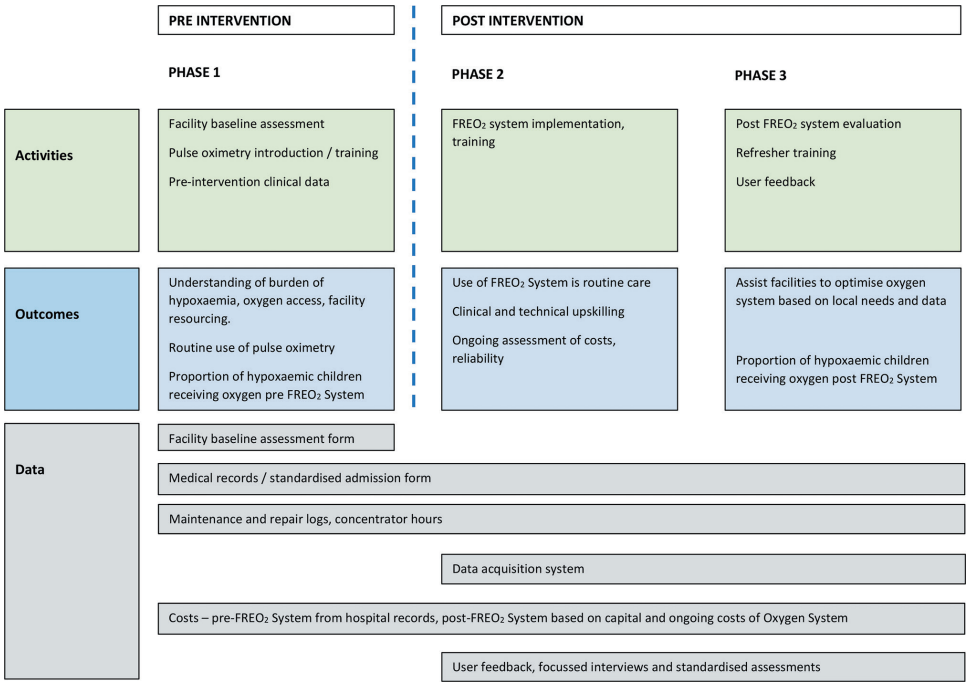

Figure 2 Project outline. Blue dotted line represents oxygen system installation. Phase 1—pre-existing oxygen supplies with improved pulse oximetry and training; phase 2—$FREO_2$ oxygen system installation and training; phase 3—programme evaluation.

and need for oxygen, is defined as oxygen saturation by pulse oximetry (SpO_2) <90%, based on WHO clinical guidelines.[22] Oxygen administration will follow local guidelines, based on WHO recommendations. We will not exclude children on the basis of age or diagnosis. We will however note when a child presents with a condition that causes non-oxygen responsive hypoxaemia (eg, cyanotic congenital heart disease).

Consent

The level of intervention is at a health facility level and not at an individual patient level, and all individual patient data are deidentified. Consent will be sought from the health facility administrator/director to eventually augment or replace the existing oxygen supplies with the $FREO_2$ system. Plain language statements will be made available to all staff and patients using the system.

Implementation

Phase 1: improved detection of hypoxaemia; use of pre-existing oxygen supplies

Figure 2 summarises the three project phases. Following baseline assessment, staff will receive refresher training in the diagnosis of hypoxaemia (±provision of pulse oximeters). Prior knowledge and training will be assessed, including a brief pretraining quiz with clinical questions on pulse oximetry and oxygen therapy based on WHO guidelines.[23] Clinical data collection will commence following this training. A standardised admission form (online supplemental appendix 3) is completed by the admitting officer for all admissions (whether or not they require oxygen), with emphasis on documenting whether a child receives oxygen and why, and the presence of any oxygen and/or power interruptions. Collecting data on all admissions, rather than only for children receiving oxygen, will provide a denominator for calculating hypoxaemia prevalence (overall and disease specific) that can be used by facilities to estimate oxygen requirements moving forward. This phase will occur over the first 3 months for each enrolled facility, with allowance for an additional month for the first enrolled facility to allow learning and adjustment of the data collection tools.

Phase 2: $FREO_2$ oxygen system and oxygen therapy training

The $FREO_2$ oxygen system will then be installed in each facility. Timing will be staggered to accommodate resource constraints, and to allow for lessons to be learnt (figure 3), with roll-out in 1–2 facilities per month. The project team will combine installation with training in equipment use, refresher of pulse oximetry and oxygen therapy training, and training in data collection.

Equipment installation will be supported by study technicians working alongside health facility staff. The $FREO_2$ oxygen system will be located away from the patient beds, with low pressure oxygen tubing piped to the bed-side of each patient. Flow is split, with individual patient flow metres at the bed-side, such that one $FREO_2$ system can supply up to four children simultaneously. The number of systems required by facilities is determined by the caseload, and projected number of hypoxaemic admissions. Based on admission numbers of the level IV facilities in Uganda, and a hypoxaemic prevalence of 10% of all admissions, we expect that one system per facility will be sufficient.

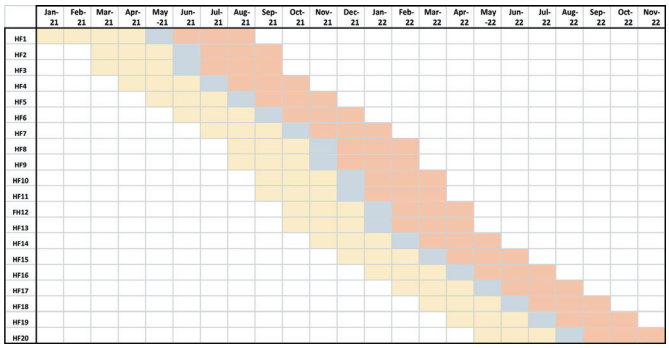

Figure 3 Projected implementation timeline. Phased implementation of $FREO_2$ oxygen system in 20 health facilities: yellow (pre oxygen system), blue (installation), red (post oxygen system). Roll-out presented over 15 steps—sequence and timing may be differ from plan. HF, health facility.

Clinical data will continue to be collected for all admissions, using the standardised admission form. In addition, a previously described data acquisition system[19 20] will be deployed at each health facility to enable remote monitoring of oxygen flow rate and purity, pressure within the LPOS and the backup oxygen cylinder, and temperature and humidity. Data will be uploaded to a remote server to assess system performance and facilitate preventative maintenance.

Phase 3: impact evaluation

Post oxygen system data will be collected for 3 months, in the same way as for the preintervention period, and will begin 2 weeks following equipment installation to account for a 'wash-out' period. The postintervention period for the last enrolled facility is expected to complete in November 2022 (figure 3).

In addition, usability assessments using the described standardised tools (online supplemental appendix 4), and semistructured interviews will be conducted in focused group interview format.[24] Postintervention data collection will be accompanied by refresher training in oxygen therapy.

Data collection and management

Clinical data will be prospectively collected for each facility using the standardised patient admission form for the duration of the study. The form will be filled-in by attending clinicians on the day of admission. On discharge, study personnel will use routine medical records to complete a discharge section, which details discharge diagnosis, duration of oxygen therapy and frequency of pulse oximetry measurements.

Clinical data will be extracted from medical records, deidentified and entered and managed using Research Electronic Data Capture (REDCap) hosted at the University of Melbourne.[25 26] Data are double entered and screened for data entry errors monthly by the study coordinator. Discrepancies are first investigated by referring to the paper form, and if required, by retrieving the child's medical record. Deidentified paper forms (admission forms) will be stored in a central research facility in Uganda.

On completion the study, finalised, deidentified data will be available from the corresponding author (RS), on reasonable request.

Outcomes

Health outcomes

There is evidence from large implementation trials for reductions in childhood mortality with implementation of pulse oximetry, and improved oxygen systems. This study does not aim to duplicate these, but rather test whether the $FREO_2$ oxygen system can improve getting oxygen to children who need it. To test this hypothesis, the primary outcome will be the proportion of hypoxaemic children receiving oxygen pre and post oxygen system. Hypoxaemia is defined as SpO2 <90% either on admission or during hospital stay.

Secondary clinical outcomes will be compared pre and post oxygen system:

- Overall, pneumonia and neonatal (age <28 days) mortality pre and post $FREO_2$ oxygen system.
- Duration of oxygen therapy per patient pre and post $FREO_2$ oxygen system.
- Length of stay pre and post $FREO_2$ oxygen system.
- Estimated amount of oxygen used per patient pre and post $FREO_2$ oxygen system.

Technical and systems outcomes

- Pre-$FREO_2$ oxygen system:
  - Number and duration of power and/or oxygen outages or interruptions, and reasons.
  - Estimated oxygen use and amount of cylinders used.
  - Oxygen purity produced by concentrators.
  - Capacity for replenishment, maintenance and repair of existing oxygen supplies.
- Post-$FREO_2$ oxygen system:
  - Number and nature of failure events that could compromise oxygen access to a hypoxaemic child.
  - Frequency, extent and duration of power outages/overvoltage.
  - Amount of oxygen delivered from LPOS device.
  - Equipment malfunctioning, maintenance and repair.
  - Amount of oxygen use and estimated amount of cylinder oxygen use.
  - Delivered oxygen purity.

Economic outcomes

All costing data for each given facility will be logged to project-specific forms by the person making the expenditure at the time the expense is incurred and recorded. The project will aim to collate initial outlay, running costs, and incidental costs. The cost to avert one hypoxaemic child not receiving oxygen because of unavailability will be calculated by dividing the total cost of the system by

the additional number of hypoxaemic children accessing oxygen.

Secondary outcomes:

- Cost of oxygen per litre and per patient pre and post oxygen system.
- Cost of oxygen per litre over time.
- Capital expenditure.
- Running costs.

Usability assessment

Standardised implementation outcome measure tools will be used: the acceptability of intervention measure, intervention appropriateness measure and the feasibility of intervention measure in the postintervention phase (online supplemental appendix 4).[27]

In addition, semistructured interviews will be conducted with health workers and health administrators in the post implementation period. Health worker interviews will capture user attitudes towards the intervention and the implementation model, including the training modules.

Sample size

Although the study design is non-randomised, sample size and power calculations were based on methods for stepped wedge cluster randomised trials, using the Stata17 program 'stepped wedge' to calculate power based on our anticipated timeline.[28 29] We assumed baseline oxygen deliver to at least 50% of hypoxaemic children and an improvement in this proportion to at least 80% post introduction of the $FREO_2$ system. We conservatively assumed a baseline hypoxaemia prevalence of 10% in all paediatric and neonatal admissions, based on a previous systematic review and a prospective study from Nigeria.[3 30] Recruitment of 4 hypoxaemic admissions per facility per month (or 40 total neonatal and paediatric admissions per month) would be able to detect a 30% improvement in oxygen access with a p value 0.01 and power 0.9. Preliminary facility data shows that these admissions numbers should be achievable.

Statistical analysis

We will use mixed-effects regression for primary and secondary analyses of effect of the oxygen system enabling comparison between facilities preintervention and postintervention and across time periods. We will analyse individual patient data, with fixed effects for time and intervention and random effects for facility and facility time interaction. Intervention effects will be expressed as an odds ratio with 95% confidence intervals. For the primary outcome, this analysis will aim to detect whether there has been a change in the proportion of hypoxaemic children receiving oxygen pre and post oxygen system. Similarly, we will analyse the impact on overall, pneumonia and neonatal mortality as secondary outcomes. For other economic and technical outcomes, pooled data from all facilities preintervention and postintervention will be compared using standard tests of significance.

Study personnel

Implementation will be led by an oxygen team, consisting of a paediatric nurse, biomedical engineer, doctor and programme manager. Training is coordinated by clinicians with the Babies and Mother Alive programme of the Brick by Brick Uganda group. Funding is provided to each facility to support clinical staff in assisting with data collection and management.

Timeline

The study covers a period of 23 months. Data collection will end 3 months after implementation of the Oxygen System in the final facility (projected November 2022; figure 3).

ETHICS AND DISSEMINATION

Ethics approval was obtained from Mbarara University of Science and Technology (MUREC 1/7) and the University of Melbourne (2021-14489-13654-2).

Results will be shared with participating health facilities in the form of reports and presentations. Facility representatives will be involved in the publication of manuscripts. Outcomes will be presented to the involved facilities, and to representatives of the Ministry of Health. We will also aim for broader dissemination, including publication in peer-reviewed journals and academic conference presentations.

Patient and public involvement

Patients and the public were not involved in the study design. The Ministry of Health and facility leadership are involved in site selection. Regular informal contact between the study team and involved facilities (clinical and technician staff) will allow adaptation of training and implementation to meet specific needs.

Ethical considerations

There is a risk that the $FREO_2$ oxygen system may displace existing oxygen systems (cylinders or concentrators) and deskill facility staff in routine upkeep and maintenance of these systems. To mitigate this, this project will prioritise facilities with poor baseline oxygen supplies, where the intervention is not detracting from already functioning oxygen systems. Pulse oximeters provided in the course of the programme will be the property of health facilities and available to them beyond the programme duration. The $FREO_2$ system will be supported for an additional 12 months after project completion, while facilities (or the Ministry of Health) choose to either enter into an agreement with FREO2 Uganda to provide ongoing maintenance, training and support for a fee or transition to a different system.

The clinical data collected as part of this project represent information that is expected to be recorded in a thorough routine clinical assessment (eg, vital signs such as heart rate), and is therefore unlikely to represent additional workload on staff. On discharge, study personnel

will extract relevant clinical data by chart review with no direct interaction with patients. Data collection forms will be deidentified when data are extracted, and all analysis and publication will use the data in deidentified form.

To study the risk of technology failure on oxygen availability, the FREO2 oxygen system has been trialled in Mbarara Regional Referral Hospital.[20] It has proven safe and reliable. To add further layers of safety, embedded within the system is a back-up oxygen cylinder, and an automatic mechanism to shift between oxygen supplies.

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Contributors SB, RS, BS and HG contributed to the conception and design of the evaluation. BS, DP, GM, SB and RR contributed to the funding application. SB, JM, DP, GM, RS, EN, DM and MS contributed to data acquisition. RS and BS wrote the initial draft of the manuscript. SB and RS contributed equally and share first authorship. All authors read, revised and approved the final manuscript.

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Competing interests BS, RR, DP are directors of FREO2 Foundation Australia.

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.

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FREO2 Oxygen for Health Centres Survey

This survey is to gain information about health centres to enable the FREO2 Foundation Australia to short list health centres for inclusion in a project to provide oxygen for peadiatric wards.
Welcome from the FREO2 Foundation and BAMA (Babies and Mothers Alive). Please take 20 minutes to complete this survey. It has been sent to around 60 health centres and hospitals in the south western Uganda. We will be choosing up to 20 centres to participate in a pilot project to provide affordable oxygen to children with respiratory diseases that is independent of a continuous electricity supply.

Add in link to plain description of technology.

Add in link to plain language statement of survey.

There are 29 questions in this survey.

Geography

This group of questions is about the location of your health centre or hospital.

1 What is the formal name of your health centre, clinic or hospital? *

Please write your answer here:

2 What is the level of your health facility?

*

Choose one of the following answers
Please choose **only one** of the following:

- ◯ Hospital
- ◯ Health Centre IV
- ◯ Health Centre III
- ◯ Clinic
- ◯ Special Clinic
- ◯ Other

3 What is the ownership of the health facility? *

Choose one of the following answers
Please choose **only one** of the following:

- ◯ MOH (Ministry of Health)
- ◯ PNFP (Private Not For Profit)
- ◯ PFP (Private for Profit)
- ◯ Other

4 What county is your health facility located in? *

Please write your answer here:

5 What sub county is your health facility located in? *

Please write your answer here:

6 About how many minutes does it take to drive to the Mbarara Regional Referal Hospital from your health facility? *

Only numbers may be entered in this field.
Please write your answer here:

minutes

7 What is the email address of the centre? *

Please write your answer here:

If the centre does not have an email address, just answer "no email"

8 What is the name of Head of this health facility? *

Please write your answer here:

9 What is the email address of the Head of the facility? *

Please write your answer here:

If they have no email address, anwer "no email"

10 What is the mobile phone number of the Head of the facility *

Please write your answer here:

Answer "no mobile number" if the Head does not have a phone.

11 What is the main source of power for the facility? *

Please write your answer here:

Power

These questions are about the electricity supply to your centre.

12 Is your centre connected to an electricity grid? *

Please choose **only one** of the following:

- ◯ Yes
- ◯ No
- ◯ Other

Answer yes to this question if the centre receives electricity that is generated by a source not under your control such as ERT, UEDCL, or a local electricity company.

13 Does the facility have any other sources of power? Feel free to add a comment to clarify sources. Choose as many options as applicable. *

Please choose all that apply and provide a comment:

- ☐ Back-up generator for Operating Theatre
- ☐ Back-up generator for wards
- ☐ Solar panels for lighting only
- ☐ Solar panels all power and lights
- ☐ Micro-hydro or some other local source
- ☐ None of the above

Other:

14 Is your main supply reliable in the short term? *

Please choose **only one** of the following:

- ◯ Very Good: Usually more than 23 hours a day
- ◯ Good: Average 20 hours a day
- ◯ OK: Average 16 hours a day
- ◯ Bad: Average 12 hours a day
- ◯ Terrible: Average <12 hours a day

15 For the worst two months of the year, how often do you have power cuts? *

Please choose **only one** of the following:

- ◯ Most days
- ◯ About twice per week
- ◯ About once per week
- ◯ About 2 times per month
- ◯ About once per month or less often

Just give you best estimate here.

16 For the worst two months of the year, how long are the power outages? Choose all options that apply to your centre. *

Please choose **all** that apply:

- ☐ Outages of less than 24 hours are common
- ☐ Outages of greater than 24 hours are common
- ☐ Outages of greater than 48 hours are common
- ☐ Outages of greater than 2 days are common
- ☐ Outages of greater than 7 days are common
- ☐ Other: _____

Oxygen Availability

These questions are about the availability of oxygen in your centre.

17 List the number of oxygen concentrators, large oxygen cylinders and pulse oximeters your health facility has in each category. *

	Total	Working and used in operating theatres	Working and used in wards	In need of repair or refill	Beyond repair or cannot be refilled
Oxygen Concentrators					
Oxygen cylinders					
Pulse Oximeters					

Your best estimate is all that is needed.

18 Where are oxygen cylinders refilled?

Please write your answer here:

19 How often are pulse oximeters used in the facility? *

Please choose **only one** of the following:

- ◯ Daily
- ◯ Several times per week
- ◯ About once per week
- ◯ Less than once per week
- ◯ Never

Make a comment on your choice here:

20 If your centre uses oxygen cylinders, how much does it cost to refill and transport the cylinders? Give your answer in UGS per cylinder.

Please write your answer here:

UGS

per cylinder

Oxygen Need

These questions are about the need for oxygen in your centre.

21 How many peadiatric patients (> 1 month and < 12 years old) and neonates (< 1 month old) are there in the following categories? *

	Average per month over last 12 months	Number in the worst month over the last 12 months
Number of paediatric patients treated each month		
Number of paediatric patients referred INTO your centre FROM other centres		
Number of paediatric patients referred OUT OF your centre TO other centres		
Number of paediatric patients with pneumonia		
Number of neonate patients (less than 1 month old)		

22 How many paediatric beds does your centre have? *

Please write your answer here:

beds

If the number varies, just give a typical value.

Physical Infrastructure

These questions are about your buildings and grounds.

23 Does your centre have about 15 square metres of external free space within 30 metres of the paediatric ward? *

Please choose **only one** of the following:

- ◯ Yes
- ◯ No
- ◯ Other

This is enough space to place a low pressure oxygen storage facilty about the size of a large water tank if it is determined that the centre needs it.

24 Does your centre have internal space of 3 square metres within 5 metres of a power outlet and 20 m of paedeatric ward for an oxygen concentrator and backup cylinders. *

Please choose **only one** of the following:

- ◯ Yes
- ◯ Yes, but no power outlet
- ◯ No
- ◯ Other

Ideally this space would not be accessible to the public. A technician would need to access the space occasionally. Nursing staff would not need regular access.

25 Does your centre have average to good coverage by 3G phone signals? *

Please choose **only one** of the following:

- ◯ Yes
- ◯ No
- ◯ Don't know

26 Does your centre have an ambulance or ready access to a private vehicle for patient transport? *

Please choose **only one** of the following:

- ◯ Yes
- ◯ No
- ◯ Other

27 Does your centre either employ or have ready access to the following support staff? *

Please choose all that apply and provide a comment:

- ☐ Biomedical Engineer
- ☐ Electrician
- ☐ Plumber
- ☐ Handyman
- ☐ Other
- ☐ None of these

Level of interest.

These questions are about the level of interest in participating in a pilot program to introduce new technology to supply a continuous supply of oxygen to your centre.

28 What is the level of interest in your centre being involved in being part of a pilot program to provide oxygen or cheaper oxygen to paediatric patients? Choose 1 for low or no interest and 5 for high interest. *

Please choose **only one** of the following:

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

29 What are the names and positions of the people who are interested in this initiative?

	Name	Position	Whats App number	Mobile phone number
The person who completed the survey				
The administrator who has a high level of interest				
The clinical person who has a high level of interest				

For this question, we are trying to find who would be local champions. This question is not mandatory. Only list people who have been asked about there willingness to be involved. If phone numbers are not available leave those fields blank.

Thank you for completing the survey. We will let you know later this year whether we have shortlisted your centre. If you need more information or want to provide feedback please contact grahamam@unimelb.edu.au

Submit your survey.
Thank you for completing this survey.

$FREO_2$ Uganda

Plain Language Statement - $FREO_2$ Health Centre Survey

This statement contains some information about a survey you have been asked to fill in.

Who is $FREO_2$?

$FREO_2$ is an Australian foundation who have been working in Uganda and other countries developing and implementing technology to provide cheaper, more reliable oxygen to children who present at health facilities with respiratory problems. $FREO_2$ is working with the Ugandan Brick by Brick Foundation and BAMA (Babies and Mothers Alive) to work on scaling up the implementation in Uganda.

What is the purpose of this survey?

We are planning to develop our knowledge of implementing oxygen technology by choosing 20 health facilities across south western Uganda. Our headquarters will be in Mbarara. This survey is being sent to about 60 facilities as part of our initial screening in order to find suitable facilities. Over the next 12 months we will be making follow up visits to around 30 facilities to choose the most appropriate ones to learn about how to implement our systems.

Is the Ministry of Health supportive of this project?

The Ministry of Health and District Health Officers are assisting us in this project and have sanctioned this survey.

How do I fill out the survey?

Our preferred method is to use the on-line version that you have received a link to. There is also a printed version if your Internet access is not so good. Because this survey is only for initial screening, we don't need very accurate answers to all the questions. Where we ask for numerical answers, please give your best estimate of the numbers. Feel free to discuss with your colleagues in your health facility to make your estimate. There are no right or wrong answers. We are looking for facilities with a range of sizes, locations and prior use of oxygen.

FREO$_2$ Uganda

Is the data I provide private and confidential?

Data from this survey will be used by FREO2 and BAMA to conduct a pilot program of supplying oxygen to health centres. We will only ever publish the results of this survey as statistical aggregates. No data will be published in a form that allows individual people, health facilities or hospitals to be identified without seeking their prior written consent. No data about individual facilities will be shared with the Ministry of Health of District Health Officers. The names and contact details collected will only be used to further the aims of this project.

The Head of your health facility may withdraw consent to use this data at any time until 31st December 2020.

Does completing this survey commit my health facility to anything?

No, the information we gather is only to help inform us about which facilities to have more discussions with. When we have selected facilities to implement our systems in, we will make a written agreement with each facility.

August 2020
Dr Graham Moore for FREO2 Foundation Australia

FREO$_2$ Uganda

Affordable oxygen for children with respiratory illness.

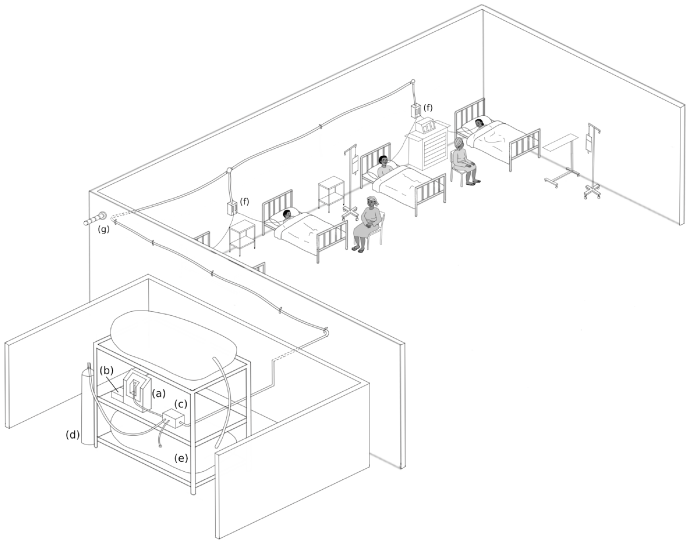
Many health facilities face challenges when it comes to ensuring an adequate supply of oxygen. We would like to introduce you to a new concept in the affordable delivery of oxygen. The FREO2 OxyLink provides a reliable continuous supply of oxygen to paediatric beds backed up with regular service and maintenance. Our aim is to provide you with a constant reliable supply of oxygen to treat children in your facility so that you can focus on their treatment with confidence.

Who is FREO$_2$ Uganda?

FREO$_2$ Uganda is a local social enterprise headquartered in Mbarara and supported by 'FREO$_2$ Foundation Australia' and 'Babies and Mothers Alive'. Our mission is to sustainably increase patient access to reliable oxygen. This will be achieved by combining technology designed for Ugandan conditions with local maintenance and support from Mbarara.

What is the technology?

Our technology - the Oxylink System - has been designed to enable health care workers to focus on patients, not oxygen concentrators and cylinders. Briefly, the system comprises an oxygen concentrator designed to meet local needs, connected to patient beds with low pressure piping and combined with temporary storage to maintain oxygen to patients during power cuts . Importantly, the technology in this system is monitored continuously to ensure high performance. Our team can remotely diagnose any problems and come to service the system within one day.



This diagram shows a typical installation. For Health Facilities with good backup power supplies there may not be a need for oxygen storage. The cylinder is only used as a last resort. The stack-lamp is to reassure the staff that the system is operational.

- *(a) The oxygen concentrator*
- *(b) PROTECT*
- *(c) Prioritizer*
- *(d) backup cylinder*
- *(e) low-pressure local storage*
- *(f) volumetric flow meter*
- *(g) stack lamp*

Image created by Isabella Anderson, inspired by a similar illustration created by David Woodroffe.

FREO$_2$ Uganda. Oxygen on demand for toto wards. www.freo2.org

$FREO_2$ Uganda

Where has the technology been tested, and how do you know it works?
$FREO_2$ Australia designed the system for Uganda and has had it working at the Mbarara Regional Referral Hospital since early 2018. We have also tested a system in Mozambique for 6 months and have begun testing systems in Nigeria. Our operations are overseen by and answerable to the MUST Research Ethics Committee.

How much will it cost?
Our aim is to save children year after year and we realise that this can only be achieved if $FREO_2$ Uganda is financially sustainable and charges Health Facilities for reliable oxygen. It is anticipated that charges will be based on the amount of oxygen used (Yakka for Oxygen), which will be monitored by $FREO_2$ Uganda and the hospital. Be reassured that the cost will be substantially lower than using oxygen cylinders alone. Because we will survive by selling availability of oxygen, we have an incentive to ensure the equipment works. During the introductory period we will discount our charges and work with Health Facilities to measure how much can be saved by switching to FREO2 Oxygen and learn what is a sustainable business model for both parties.

What is required of participating Health Facilities?
Facilities will need to facilitate the installation by providing at most 4 m^2 inside and up to 16 m^2 outside, near to the paediatric ward. A standard power outlet is required for the concentrator. Staff will be required to undertake a short training session in using the equipment and may require a short training to update clinical skills for oxygen use.

How will Health Facilities be selected?
Health facilities will be prioritised according to a number of selection criteria, including:

- Enthusiasm: Is reliable oxygen a priority for Health Care Workers *and* Administrators?
- Location: Is the Health Facility readily accessible to FREO2 Uganda staff in Mbarara, 3G phone coverage and a standard electricity supply?
- Impact: Is the introduction of reliable oxygen likely to substantially improve health outcomes?

What next?
If you want to participate in the initial roll-out of 20 systems, or just want more information contact Sheillah Bagayana Mutetire by email at sheillah@freo2.org or WhatsApp on +256-784 717001

$FREO_2$ Uganda. Oxygen on demand for toto wards. www.freo2.org

Baseline Data

Record ID	_____
Health Facility Name	_____
Health Facility Ownership	☐ MoH ☐ Private ☐ Faith Based ☐ NFP
Health Facility In-charge	_____
Assessors	_____
Date of Assessment	_____

Part 1 - Case Load	
Number of paediatric beds	_____
Number of neonatal beds	_____

Part 1 - Case Load - Paeds	
For last 3 months, number of paediatric admissions - start date	_____
For last 3 months, number of paediatric admissions - number	_____
For last 3 months, number of paediatric admissions - number of females	_____
For last 3 months, number of paediatric deaths	_____

Part 1 0 Case Load - Neonates	
For last 3 months, number of neonate admissions - start date	_____
For last 3 months, number of neonate admissions - number	_____
For last 3 months, number of neonate admissions - number of females	_____
For last 3 months, number of neonate deaths	_____

Part 1 - Case Load - Today	
Today, how many children are receiving oxygen? Please document flow (l/m), number of days on oxygen and oxygen source	_____
Patient 1 flow LPM	_____
Patient 1 duration on oxygen (days)	_____
Patient 1 O2 source	_____
Patient 2 flow LPM	_____
Patient 2 duration on oxygen (days)	_____
Patient 2 O2 source	_____
Patient 3 flow LPM	_____
Patient 3 duration on oxygen (days)	_____
Patient 3 O2 source	_____
Patient 4 flow LPM	_____
Patient 4 duration on oxygen (days)	_____
Patient 4 O2 source	_____

Part 2 Catchment and Referal

What catchment area does this facility serve?	_____
What is the estimated catchment population?	_____
What is the nearest health facility (Name)	_____
What is the distance to the nearest health facility?	_____
Which other facilities refer patients to this facility? (Referral FROM)	_____
Which facilities are patients from this facility sent to? (Referral TO)	_____
Is transport available for referral of sick children to other facilities?	○ Yes ○ No
If yes, describe	_____
Is oxygen available during transport?	○ Yes ○ No

Part 3 - Staffing

How many staff does the health facility employ (both medical and non-medical)	_____
How many doctors	_____
Howmany midwives	_____
How many nurses	_____
How many CHW	_____
Describe day/night staffing, i.e. number of shifts and staffing	_____
What is the average clinical staff capability in administering oxygen therapy?	☐ Proficient ☐ Average ☐ Basic ☐ Other

Other - describe	_____
How often do staff receive training on oxygen administration and monitoring?	☐ Monthly ☐ Quarterly ☐ Annually ☐ Never ☐ Other
Other - describe	_____

Part 4 - Power Supply

What sources of power are available? Tick all that apply	☐ Mains ☐ Generator ☐ Solar ☐ Hydro ☐ Other
Other - describe	_____
How many hours per day is power available on average	☐ < 6 ☐ 6-12 ☐ 12-18 ☐ >18
How often is power interrupted?	☐ Monthly ☐ weekly ☐ daily ☐ hourly
How many power outages are there per day/ week/ month depending on response in above question?	_____
What is the average duration of each power outage?	_____
Who pays for the power	☐ MoH ☐ Self ☐ NFP org ☐ Other
Other - describe	_____
What is the average cost of power per month?	_____

Part 5 - Oxygen Supply

What is the main source of oxygen?	☐ Concentrator ☐ Stand alone cylinder ☐ Piped from cylinder ☐ Piped from O2 plant ☐ Other
Other - describe	_____
Is there a back-up source of oxygen? Yes/No	○ Yes ○ No
Is there a back-up source of oxygen? Please specify what this is.	_____
How many oxygen supply points are there at this point in time?	_____
Can you recall a day, in the last month, where oxygen was unavailable for a child who needed it? Why?	_____

Part 5 - Oxygen Supply - concentrators

How many oxygen concentrators are available?	_____
How many concentrators are being used?	_____
How many concentrators are producing >=85% O2 concentration (test using oxygen sensor)	_____
Do the concentrators undergo regular servicing?	○ Yes ○ No
What is the frequency of servicing?	_____
Who conducts the servicing?	_____
What is the annual cost of servicing?	_____
Since installation, have any of the concentrators required repair?	○ Yes ○ No

Part 5 - Oxygen Supply - Cylinders

How many oxygen cylinders are available?	_____
Where are the cylinders filled? Include distance	_____
What is the cost of refilling each cylinder?	_____
What is the facilitys average consumption/ month in terms of cylinder usage?	_____
Who is responsible for filling the cylinders?	_____
How many cylinders on the childrens ward are fully functioning on day of assessment? (has gas, regulator, tubing, canula)	_____
What is the problem with the cylinders that are not working?	_____

Part 6 - Pulse Oximetry

Is pulse oximetry available on the ward?	○ Yes ○ No
If pulse oximetry is not available, how are oxygen requirements determined?	☐ WHO clinical signs ☐ Oterh guidelines ☐ Don't know
How many oximeters are available in the paediatric ward and entire facility?	_____
How many pulse oximeters are functioning on day of assessment?	_____
Is pulse oximetry done on every paediatric admission?	○ Yes ○ No
Is pulse oximetry done on every child on oxygen?	○ Yes ○ No
How frequently per 24 hours is pulse oximetry done for children on oxygen?	_____

Part 7 Asset and Equipment Status

How is procurement and refills managed and by whom?	_____
Is the oxygen equipment accessible?	_____
Are equipment spare parts accessible?	_____
How is it stored and what are the conditions?	_____
Is there an equipment register and is it up to date?	_____
Is there 15 m2 of external free space within 30 m of the paediatric ward?	_____
Is there 3 m2 of internal space	_____
Is there internet / 3G phone coverage?	_____
Does the facility have an ambulance?	_____

Part 8 - Oxygen Use

In the last month, how many children received oxygen?	_____
In the last month, how many children had an admission SpO2< 90%?	_____
In the last month, how long does it take prior to patient getting oxygen access (delay?)	_____
In the last month, what is the average duration of oxygen access?	_____
In the last month, how many oxygen cylinders have been refilled?	_____
Install date Conc 1	_____
Install date Conc 2	_____

Install date Conc 3	_____
Install date Conc 4	_____
Hour Meter Conc 1	_____
Hour Meter Conc 2	_____
Hour Meter Conc 3	_____
Hour Meter Conc 4	_____
Is there a protocol for oxygen administration?	_____

Part 9 - Oxygen Cost	
What is the estimated annual cost of oxygen to the facility?	_____
What is the breakdown of the spend (capex, opex e.g., new systems, refills, servicing, maintenance, transport)	_____
How much are patients being charged for oxygen (per hour / day or per litre/ treatment)?	_____
What is the total cost to the family of a 5-year-old admitted with pneumonia (assume average 3 days admission, include admission fees, medications, consumables, laboratory)	_____
What is the allocated budget for oxygen (and % of total budget)?	_____
Who funds the oxygen supply? E.g. grant, government, patient fees	_____
Who pays for staff training on oxygen therapy (if this is offered in the facility)	_____

Part 10 - Supply Chain

What is the ordering and receiving process for oxygen equipment and cylinder refills?	_____
Who provides the supply chain services?	_____
How long does procurement take? e.g., refills	_____
What is working well with the supply chain?	_____
What is not working well with the supply chain?	_____

Part 11 - Partners

Who does the facility partner with? (funding, government, implementing, training)	_____
Who does the facility have contract relationships with?	_____
What's the nature of these partnerships?	_____
What's working and not working with these relationships?	_____

Part 12 - Willingness to pay.

How much is the facility willing to pay for oxygen?	_____
How would this be funded?	_____
Who's involved in the financial decision making?	_____
Would the facility be willing to pay for oxygen training and systems maintenance?	_____
What would they pay for training, maintenance?	_____
Do they plan to charge the customer / patient in the future?	○ Yes ○ No
Does the facility have income generating activities?	○ Yes ○ No
For your next budget, what are your top spending priorities?	_____

Part 12 - New Technologies	
Are you familiar with the work underway in Uganda around solar powered oxygen concentrators?	○ Yes ○ No
Would the facility be willing to purchase newer / novel technologies such as solar powered oxygen concentrators?	○ Yes ○ No
Other - describe	_____
Would the facility be willing to purchase newer / novel technologies such as local oxygen storage?	○ Yes ○ No
Other - describe	_____

Confidential

Admission Form

Study ID	_____ (Automatically generated by REDCap)
Date of Admission	_____ (D-M-Y)
Facility	◯ Kalisizo: KAL ◯ Rakai: RAK ◯ Kisiizi: KIS ◯ Kebisoni: KEB ◯ Kakuuto: KAK ◯ Mastercare Bethlehem: MAB ◯ Rukungiri HC IV: RUK ◯ North Kigezi HC IV: KIG ◯ St Joseph's Kyamuliibwa HC IV: KYA ◯ Butenga HC IV: BUT ◯ Kyazanga HC IV: KZG ◯ Our Lady of Good Health Rushoroza: RUS ◯ Rugarama Hospital: RUG ◯ CoU Bwindi Community Hospital: BCH ◯ Kalangala HC IV: KLG ◯ Itoojo Hospital: ITO ◯ Villa Maria Hospital: VMH ◯ Nyakibaale Hospital: NYA ◯ Ishaka Adventist Hospital: ISH ◯ Other
Facility (Other)	_____ (Facility (Other) Description)
Ward	◯ Paediatric ◯ Neonatal ◯ Maternity ◯ Other
Ward (Other)	_____ (Descripton of "Other" ward.)
Patient ID Number	_____ (Three letter code for the health centre - one letter code for the neo or paed ward (n or p) - two digit code for the year of admission (always 21 or 22) - two digit code for the month of admission (01 to 12) - patient number assigned by the health centre (usually three digits that should include leading zeroes. e.g. KAL-P-2101-034))
Sex	◯ Female ◯ Male

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Age at Admission - Provide DOB (preferred) or Age in Year / Months / Weeks / Days

DOB _____

Age (Years) _____

Age (Months) _____

Age (Weeks) _____

Age (Days) _____

Admission Measurements

SpO2 on admission _____ (%)

Repiratory Rate on Admission _____

Pulse Rate on admission _____ (Beats per minute)

Temperature _____ (degC)

Symptom / Sign

	Yes	No
History of Fever	○	○
Chest indrawing / recession	○	○
Cyanosis	○	○
Grunting	○	○
Head bob	○	○
Nasal Flaring	○	○
Depressed mental state / lethargy	○	○
Inability to drink or feed	○	○
Cough	○	○

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Provisional diagnosis (tick all that apply)

- ☐ Pneumonia
- ☐ Malaria
- ☐ Diarrhoea
- ☐ Meningitis
- ☐ Malnutrition
- ☐ Tuberculosis
- ☐ Sepsis (specify source) incl. neonatal sepsis
- ☐ Prematurity complications (i.e. respiratory distress syndrome, low birth weight etc.)
- ☐ Anaemia
- ☐ Birth asphyxia / neonatal encephalopathy
- ☐ Injuries / trauma
- ☐ Other

Sepsis source

_____
(Example: Skin Sepsis or Chest Sepsis)

Provisional Diagnosis Other Description

_____

On Discharge (STUDY PERSONELL USE)

Discharge Diagnosis (tick all that apply)

- ☐ Pneumonia
- ☐ Malaria
- ☐ Diarrhoea
- ☐ Meningitis
- ☐ Malnutrition
- ☐ Tuberculosis
- ☐ Sepsis (specify source) incl neonatal sepsis
- ☐ Prematurity complications
- ☐ Other
- ☐ Anaemia
- ☐ Birth asphyxia / neonatal encephalopathy
- ☐ Injuries / trauma

Discharge Diagnosis Sepsis Source

_____
(Example: Skin Sepsis or Chest Sepsis)

Other Description

_____

Recieved Oxygen?

- ◯ Yes
- ◯ No

Date O2 Commenced

_____

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Date O2 Ceased	_____
Reason for not receiving oxygen (tick all applicable)	☐ SpO2 > 90% throughout admission ☐ No clinical signs of hypoxaemia ☐ Oxygen not available ☐ Oxygen tubing or prongs not available ☐ Unknown ☐ Other
Was SpO2 documented at least twice on:	☐ Day 1 ☐ Day 2 ☐ Day 3
Were there any observations on admission or during hospital stay that were SpO2 < 90%	◯ Yes ◯ No
Was the child on oxygen or commenced on oxygen for any period of SpO2 < 90% on admission or during their hospital stay?	◯ Yes ◯ No
Was oxygen unavailable to this child at any time for more than 10 minutes during their admission while they still needed it?	◯ Yes ◯ No
Date of discharge (must not be before [ps_date_admission]	_____
Name of Discharging Staff	_____ (Field is hidden)
Outcome	◯ Discharged home well (expected to survive) ◯ Discharged against medical advice ◯ Discharged home unwell (expected to die) ◯ Transferred to another facility. ◯ Died

Acceptability of Intervention Measure (AIM), Intervention Appropriateness Measure (IAM), & Feasibility of Intervention Measure

Acceptability		
1	The $FREO_2$ Oxygen System meets my approval	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree
2	The $FREO_2$ Oxygen System is appealing to me	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree
3	I like the $FREO_2$ Oxygen System	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree
4	I welcome the $FREO_2$ Oxygen System in my facility	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree
Appropriateness		
1	The $FREO_2$ Oxygen System seems fitting for use in my facility	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree
2	The $FREO_2$ Oxygen System seems suitable to my facility	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree
3	The $FREO_2$ Oxygen System seems applicable to my facility	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree
4	The $FREO_2$ Oxygen System seems like a good match to my facility	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree
Feasibility		
1	The $FREO_2$ Oxygen System seems implementable in my facility	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree

		☐5 Completely agree
2	Giving oxygen using the $FREO_2$ Oxygen System seems possible	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree
3	Giving oxygen using the $FreO_2$ Oxygen System seems doable	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree
4	The $FREO_2$ Oxygen System seems easy to use	☐1 Completely disagree ☐2 Disagree ☐3 Neither disagree or agree ☐4 Agree ☐5 Completely agree