FREO\textsubscript{2} oxygen solutions: the Low-Pressure Oxygen Storage system and FREO\textsubscript{2} Siphon

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Every health facility that cares for in-patients must have a reliable supply of oxygen
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The problem: Child mortality due to hypoxia (mostly Pneumonia…)

- 920,000 deaths per year in under-fives alone
- Half never reach the health service
- Amongst the others most don’t get past the front-line health facilities
Looking for solutions

• Cylinders seem very expensive.
• Oxygen concentrators show promise, BUT
  • They have short lives in ‘grey power’ settings
  • When the power is off the oxygen flow stops
  • They are often used inefficiently.
Looking for solutions

• Solutions must:
  • Be robust, long-lasting, low-maintenance, and low-cost (to install, run and maintain);
  • Supply oxygen during power cuts or without electricity;
  • Be highly useable by non-doctor health workers (hence must be packaged with algorithms, pulse oximetry, training and supervision);
  • Require a minimum of health worker intervention.
The Low-Pressure Oxygen Storage (LPOS) system
Accelerated testing:

• >2000 fill/empty cycles in the laboratory
• 24 hours in situ in Mbarara
Thirty days on grid in Mbarara:

- Constant 1.2 litre/minute to simulated ‘patient’
- Power off 2.9% of the total; duration 1-176 minutes (mean 36.2, median 18.5).

In operation since July 2016: Ethics proposal now in for clinical use.
Grid power → \( \text{PROTECT} \) → \( \text{CONCENTRATOR} \)

Battery → \( \text{PROTECT} \) → \( \text{CONCENTRATOR} \)

Grid power → \( \text{PROTECT} \) → \( \text{CONCENTRATOR} \) → LPOS

Grid power → System 1,2 or 3 → \( \text{PRIORITIZER} \) → \( O_2 \) → LPOS

Grid power → \( \text{PRIORITIZER} \) → \( \text{LPOS} \)

Grid power → \( \text{LPOS} \)

Off Grid:

Stream → \( \text{Siphon Vacuum} \) → \( \text{FREO}_2 \text{ VSA CONCENTRATOR} \)

Off Grid → \( \text{Siphon Vacuum} \) → \( \text{FREO}_2 \text{ VSA CONCENTRATOR} \)

Off Grid → \( \text{Extremely Efficient} \)
FREO$_2$ Siphon: An electricity-free oxygen concentrator
Oxygen Concentration Vs Time

Oxygen Concentration (%)

Time (s)

[Graph showing oxygen concentration over time with a line at 90.1% for average oxygen concentration]
Oxygen Flow Vs Time

Oxygen Flow (LPM)

Time (s)

Average Oxygen flow = 4 LPM
Getting to ‘every facility with in-patients’

• Many actors, each with different triggers to action:
  • Health Care Workers – Usability, labour-saving
  • Ministries of Health – Fit with plans, workforce, costs
  • Normative organizations – Peer-reviewed evidence
  • Regulatory authorities – Technical dossiers
  • Funding agencies – Cost-effectiveness, good manufacturing practices, conformity to standards

• Multiple data streams needed
Getting to ‘every facility with in-patients’

• *Technical data*: regarding the design and functioning of the devices under field conditions;

• *Clinical data*: comparing current treatment of hypoxic illnesses with outcomes when the devices are in place; and

• *Health economic data*: to quantify the costs of installation, running, and maintaining the devices – the full lifetime cost of ownership.
Getting to ‘every facility with in-patients’

• ‘Before and After’ studies:
  • Approx. 3 months baseline data (all 3 data streams), to confirm the devices are robust and collect baseline clinical data;
  • Begin supplying oxygen to (usually 6) designated beds;
  • Minimum of 3 months data in each stream to compare with the ‘before’ data;
  • Proportions of children: getting all needed O2; with sequelae; dying. Length of stay.
Getting to ‘every facility with in-patients’

• In the next two years:
  • ‘Before and After’ studies in all the relevant levels of the health servicer in *at least* two countries.
  • Social enterprise model for maintenance.
  • Regulatory approval.

• On the horizon:
  • A large-scale trial big enough to show unequivocal effects on mortality. (A stepped-wedge randomised controlled trial?)
  • Partnership with a manufacturing/marketing organisation.
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Non-doctor health workers

• Currently oxygen is generally prescribed by doctors, and administered by nurses

• Pulse oximetry is still uncommon, and clinical signs are not reliable for diagnosis of hypoxia
  • So there is a mismatch between need for oxygen and receipt of oxygen

• We will need to develop simple algorithms for diagnosis and monitoring

• ‘Task shifting’ is well established in health care – but it demands good training and supervision
Maintenance

• Concentrators need regular maintenance
• FREO$_2$ devices will need some too
• Trained bio-medical engineers are scarce
• Ministries of Health have no budget for more
• We propose ‘oxygen technicians’
• Might a local social enterprise/small business model work?
Publications:

Sobott BA, Peake DJ, Black JFP, Rassool RP. FREO₂: An electricity free oxygen concentrator. *pneumonia* 2015;6:115–119

LPOS
Low Pressure Oxygen Storage System

- Electricity Grid or Generator
- Oxygen Concentrator
- O₂ Cylinder
- LPOS MIXER
- LPOS STORE
- Hypoxic Patients
- Low-cost, low-pressure tubing for oxygen delivery (up to 50m)

The automatic flow director switches to reserve (STORE or cylinder) when the power fails, providing a continuous supply.

The Freo2 power conditioner stabilizes the supply and prevents power surges etc from damaging the concentrator.

The flexible LPOS Storage system can be scaled to provide continuous supply even during extended black-outs.