Public health

Field trial of oxygen concentrators in upper Egypt

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Technical problems in developing countries often require more than just technological solutions. Many small hospitals in rural areas are without a reliable oxygen supply; small oxygen concentrators offer a solution, but simply sending out machines is ineffective. This account details the setting up and first year's operation of a project to test oxygen concentrations in a developing country. A co-ordinated strategy has been developed to include machines, supplies, education, training, and feedback. Initial results are encouraging, and support the idea that suitably installed and maintained concentrations can have a valuable role in bringing oxygen therapy to patients and hospitals in countries which have so far been denied it.

Oxygen concentrators have the potential to supply oxygen to hospitals in remote locations where the high cost and transport difficulties of cylinder supplies often result in shortages. In many developing countries the supply of oxygen cylinders to district hospitals is inadequate. Oxygen supplied in cylinders is expensive because low-temperature liquefaction distillation processes used in manufacture incur high energy costs. Cylinders may have to be purchased rather than rented, transport costs are high, and many cylinders are lost in transit. Oxygen concentrators use gas chromatography to separate oxygen from room air. This low-energy process requires only a continuous 350 Watt supply of electricity from mains or generator. Small concentrators were initially used in industrialised countries as a cheap source of supply for domiciliary users.[1,2] In 1989, the World Health Organization (WHO) and the World Federation of Societies of Anaesthesiologists agreed a set of performance criteria which concentrators should meet to survive the demanding conditions found in developing countries.[3] Since the publication of this standard, many manufacturers have submitted concentrators for testing to the high specifications it demands—up to now only three machines have passed all the tests (details available from the Programme on Clinical Technology, WHO, 1211 Geneva 27, Switzerland).

The Egyptian field trial

The technical performance of concentrators is well understood. In some developing countries such as Malawi they have been successfully introduced[4,5] but a controlled field trial, examining both the machines' performance and their use by different groups of health workers has not been done. In 1993, a project was set up with the support of the Egyptian Ministry of Health (Child Survival Project), WHO, and United States Aid for International Development. The aim was to install concentrators in district hospitals; train technicians to install, regularly inspect, service, and repair them with a detailed reporting system to analyse the performance and usefulness of each machine over 5 years. Although most machines will last much longer than this, concentrators can save enough money (compared with cylinders) to pay for their own purchase cost in 6 months of use.[6]

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Setting up the trial

A project such as this involves not just buying machines, but setting up a system of technology whose necessary components are shown in the table. Different people and skills are needed to introduce such a system to a developing country—is likely to fail unless it meets these requirements.

The project team is made up of:

- users (doctors and nurses);
- a registered clinical user in each hospital responsible for overall clinical use and reporting;
- a group of technicians who travel regularly among test hospitals to service and repair the machines;
- a field co-ordinator who also makes frequent visits to supervise and instruct technicians and users;
- trainers to lead courses and prepare training materials;
- representatives of the supporting agencies;
- an overall co-ordinator.

Egypt was identified as a suitable location for such a trial because it has many suitable district hospitals with good communications and year-round access. The decision to site the trial in Upper Egypt (figure 1) was made by the Egyptian Ministry of Health on the basis of their knowledge of local conditions, and the ability to link resources with other projects.

Upper Egypt has a high infant-mortality rate from pneumonia and acute respiratory infections (ARI), and improvement in oxygen supplies complements other programmes already set up to reduce this. The location has the added advantage that extreme environmental conditions—eg, summer temperatures regularly in excess of 40°C, high humidity, and dust—occur in this part of the country. The combination of a difficult physical environment and inexperienced personnel constitute a severe but realistic test for any technology. Thirteen hospitals were selected for installation of concentrators in

System requirement	Means of achievement
Be shown to be suitable for its intended use	Use only WHO approved concentrators
Be supplied through reliable channels	Supply through local health governates
Be put in the right environment	Inspect all test sites before installation
Be understood by the users	Identify and train a registered user at each site
Be maintained and repaired by suitably trained people	Identify and train technicians to visit regularly
Be supported with spare parts from within the project budget	Monitor supplies of spares
Be monitored in location and use by a reporting system	Detailed logbook reporting of use and problems

Table: **Components of a technology system**

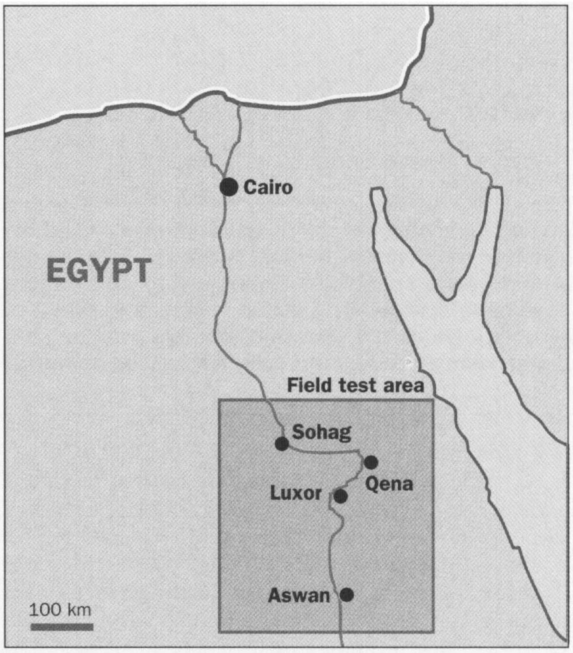

Figure 1: **Egypt, showing field test area**

the four governorates of Upper Egypt (figure 2).

A field co-ordinator was selected and appointed through the Child Survival Project of the Egyptian Ministry of Health. The appointee was a bioengineer with experience of medical equipment and was responsible for visiting, supervising, and training the users and technicians. She was supported by a colleague (NK) at the Child Survival Project, by the author (DP) of the concentrator instruction and repair manuals, by the supporting agencies, and by the overall co-ordinator (MD). In order to ensure full data collection, a decision was taken to limit the study to a small (20–30) group of concentrators. The concentrators were selected from a list of the three models which met WHO performance criteria. WHO requires approved concentrators to be shipped with a 2-year supply of essential spare parts. Purchasing finance was arranged from support-agency funds through normal procurement channels. Technical advice was sought and purchases made of oxygen analysers and other test equipment needed for the technicians.

Training

Six technicians selected by the Egyptian Ministry of Health but without experience of concentrators attended an initial training course, at which they were taught how to unpack, set up, install, and carry out routine maintenance on the machines. The author of a purpose-designed manual (DP) was responsible for the planning and conduct of the course. The field co-ordinator acted as translator, and the course participants working together produced a clear Arabic translation of the manual. This format was successfully repeated a year later with a fault diagnosis and repair course. Both courses took place in the field test area.

At an initial visit to each test hospital, a registered user from the medical staff was identified (these were mostly paediatricians, the main users of oxygen in treating ARI). A full explanation of the function of concentrators and of the trial was given, and further training materials sent to each person. It was evident that users needed clear guidelines both in the selection of patients for oxygen therapy and in the clinical use of the apparatus.

Record keeping

For data collection, a pre-printed Arabic logbook was supplied with each machine, containing a detailed record of machine usage (case recording) to be kept by the registered user. In the same book any faults or problems are noted, and technicians' inspection and repair notes kept. The pages of the books are detachable; completed sections are removed by the technicians each time they visit for regular maintenance or repair, and forwarded to the field co-ordinator to maintain an up-to-date view of the overall situation.

Inspection visits

In addition to the technicians' visits every 3–4 months, the field co-ordinator visited the test hospitals regularly, and the overall co-ordinator, and representatives of supporting agencies visited annually. These visits allow reappraisal and re-emphasise the importance of good data collection. Those who collect this important information are paid a small financial incentive.

Findings after 12 months

The first major review was carried out after a field visit in January, 1995. This coincided with an advanced technicians' training course. In each of nine hospitals, the registered users were interviewed and the 22 machines and their logbooks inspected. Inspection of the machines' internal timers showed that some had been used extensively (figure 3).

The concentrators had been well accepted and all had been used. Even in the smallest hospitals, where they had been least used, each machine had been used for an average of 13 hours per week; in the larger hospitals, many of which care for premature babies, the machines had run almost continuously since installation. The range of illnesses treated is shown in figure 4; ARI and low birthweight were the main indications for oxygen therapy (67% of cases).

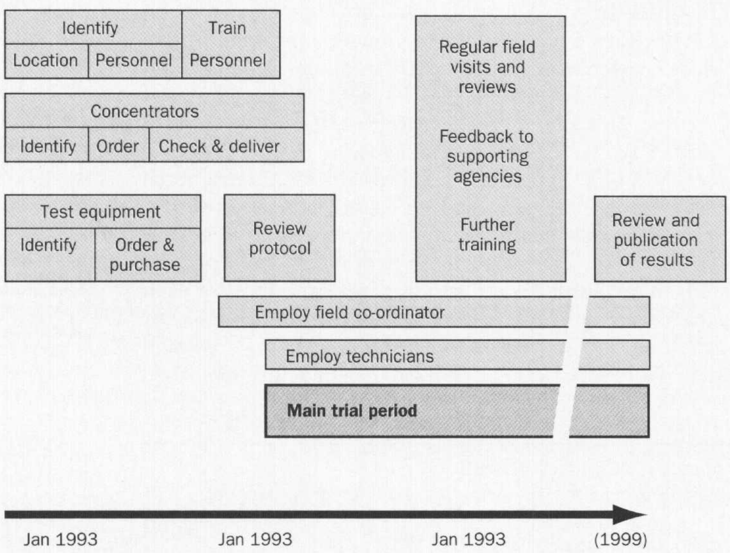

Figure 2: **Timechart of project**

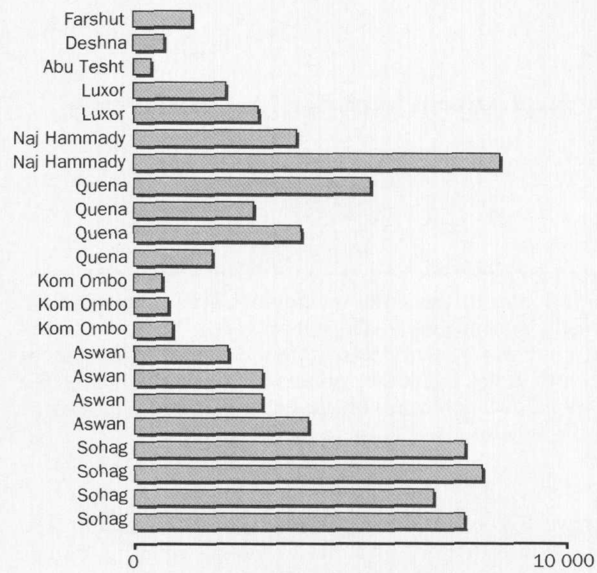

Figure 3: **Use of concentrators in first year**

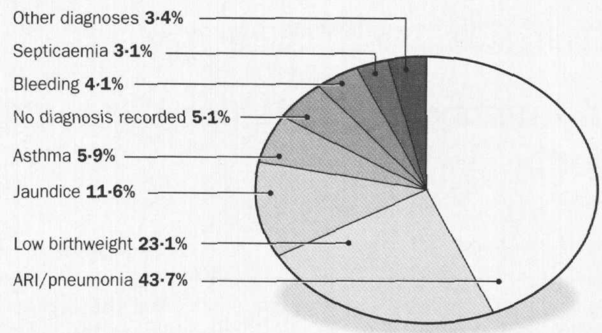

Figure 4: **Diagnoses recorded ARI=acute respiratory infection**

Performance

Of the 22 machines inspected, one had developed a fault and had been repaired by the local technicians; one other was not functioning. It was taken to the training course, where the technicians were able to diagnose and repair the fault and return it to service. Two machines had flowmeter faults (probably caused by user error), which did not prevent the machines functioning, and were readjusted. Over the second 6 months of the trial, regular measurements of output oxygen concentrations were made for each machine. Ignoring the one breakdown, the lowest recorded concentration was 79% and the mean 89·2%. There have been no other notable problems, even though the concept and technology of concentrators was new to both the users and technicians at the beginning of the trial. Day-to-day running of the trial has been entirely in the hands of local staff, with only 10 working days on field visits and courses by each of the two external advisers.

On the basis of observations made after a year, we calculate that the 22 machines inspected in January, 1995, had in the previous 12 moths run for an average of 3712 hours each (just over 5 months continuous use) and have produced more than 18 million litres of oxygen, much of it for patients in hospitals whose previous oxygen supply was unreliable.

Users' response and problems

It is gratifying to find that the results of WHO's laboratory testing are borne out in field results, but we are also concerned with human factors in the application of this technology. Most of the users had a good basic understanding of the indications and application of oxygen therapy. We sought to reinforce this with advice given by the co-ordinators and field technicians.

In a few hospitals the users had sought to protect their new machines and only use them when cylinder supplies failed. This not only hindered effective testing of the concentrator, but also meant using an expensive resource (cylinder oxygen) instead of a cheaper one. Users were sometimes confused about oxygen-delivery systems (eg, humidifiers, delivery tubing, incubators, face masks, nasal oxygen catheters, and prongs). A simple explanatory sheet in Arabic with this information has now been supplied to go with each concentrator.

One machine had been installed inside a wooden cupboard, in a room clearly not used for treating patients. It is now being resited in a more useful location.

Many of the machines were dusty and needed new filters, but the location of the spare filters originally supplied could not be determined. Action has been taken to obtain these cheap but vital spare parts, and to review and improve the project supplies system.

Conclusion

Too many aid projects have failed because technology (often untested) is dumped on users who are untrained and unsupported in its use. Intensive local monitoring and supervision are the key features of this project. Plans are now in place for continued support of the infrastructure throughout the 5-year trial period. Oxygen concentrators are not a universal replacement for oxygen cylinders; they can only given an assured supply when either a reserve power supply or a few emergency cylinders of oxygen are available for power cuts, but they can provide a very substantial increase in oxygen availability at district hospital level. The machines currently on trial are small, and only suitable for treating individuals or small groups of up to 4 patients. If the technology and support system do prove successful in Egypt, manufacturers may be encouraged to produce larger machines capable of producing perhaps 20 L/min which would have a greatly extended scope in wards, emergency rooms, and operating theatres.

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