ORIGINAL ARTICLE

Use of a portable oxygen concentrator and its effect on the overall functionality of a remote field medical unit at 3650 meters elevation

Rehan Masroor, MBBS, MCPS, FCPS*, Amjad Iqbal, MBBS, FCPS**, Khalid Buland, MBBS, MCPS, FCPS***, Waqas Ahmad Kazi, MBBS, FCPS****

**Consultant Anesthesiologist, PAF Hospital Mianwali (Pakistan)*
***Head, Department of Anesthesiology and Pain Management, Combined Military Hospital, Abbottabad (Pakistan)*
****Consultant Anesthesiologist, Department of Anesthesiology & Pain Management, Combined Military Hospital, Rawalpindi (Pakistan)*
*****Advisor in Anesthesiology Pakistan Army*

Correspondence: Major Dr. Rehan Masroor, MBBS, MCPS, FCPS, Consultant Anesthesiologist, PAF Hospital, Mianwali (Pakistan); Cell: 0345-5893715; E-mail: docrehan@gmail.com

ABSTRACT

Background: The supply of oxygen is a complex issue in disaster situations and snowbound mountainous areas. Innovative solutions are required for safe anesthesia practice; one such innovation is a small portable oxygen concentrator for oxygen therapy in remote austere environment. We conducted this study to ascertain the economy achieved by employing this equipment to improve functionality of a surgical unit in an austere environment.

Methods: Retrospective review of patient records and cylinder consumption from 1st October 2008 to 30th March 2009 was carried out and this data was classified as group A. While group B consisted of all the patients, who required oxygen therapy from 1st October 2009 to 30th March 2010, and were divided into sub-groups, on the basis of type of anesthesia or oxygen therapy. They were further categorized with respect to use of oxygen concentrator or oxygen cylinder for oxygen provision. The percentages of patients in these subgroups were summed to ascertain the economy achieved in the use of oxygen cylinders by comparing cylinder/patient ratio between group A and B respectively. Percentage economy achieved was then calculated.

Results: In group A cylinder/patient ratio (21/53) was '0.4' as compared to (3/81) '0.03' of group B. Percentage economy achieved was hence found to be (0.4/0.03%)) 1333%.

Conclusion: Use of oxygen concentrator is an innovation which is economical, easily applicable and highly recommended in remote austere environments..

Key Words: Anesthesiologist; Oxygen concentrator; Safety of equipment; Military anesthesia; Oxygen delivery systems

Citation: Masroor R, Iqbal A, Buland K, Kazi WA. Use of a portable oxygen concentrator and its effect on the overall functionality of a remote field medical unit at 3650 meters elevation. Anaesth Pain & Intensive Care 2013;17(1):45-50

INTRODUCTION

Anesthesia provision in the battlefield, hostile environment or in disaster situations encompasses the skills of resuscitation, the art of anesthesia, postoperative intensive care and safe patient transfer.[1] The field conditions demand anesthetic techniques that allow rapid recovery and early evacuation.[2-4] Experience has shown us that austerity is powerless in preventing success and high standards of care when faced with diligence and ingenuity.[5]

Pakistan Armed Forces anesthesiologists employed in the highest battlefield of world i.e. Siachen Glaciers in Gilgit Baltistan or in parts of Tribal Areas of Khyber Pukhtunkhwa province have to provide anesthesia services in far less than ideal circumstances due to the remoteness of the areas. Austerity usually connotes a location in an underdeveloped region of the world, harsh physical environment or combat zones. Austere conditions may occur even in the most developed countries/areas when there are constraints in the delivery of care such as loss of basic infrastructure, degraded communications, and movement due to natural or manmade disasters.[6]

Limited medical supplies, especially of pressurized oxygen cylinders can put any healthcare provider under stress in such circumstances. Transport of oxygen cylinders across snow bound peaks is difficult and carriage by helicopters impossible due to its associated hazards. Supply of oxygen becomes even more complex in the war like disaster situations.[7] Initial solutions for forward medical teams should include carrying limited amounts of tank gaseous oxygen and using small portable oxygen concentrators.

This study was carried out to ascertain the efficacy of the portable oxygen concentrator and its effect on overall functionality of a remote surgical set up.

METHODOLOGY

This study was based on the practical experience of the anesthesiologists employed in an Independent Mobile Surgical Team (MST), which is located at an approximate height of 3650 meters (11000 feet) in northern areas of Pakistan. Approximately 12,000–15,000 people are dependent upon this MST for every type of surgical and medical needs. It remains snowbound for about 6-7 months every year and the supplies reach here only by helicopters. Therefore, all the stores (drugs and pre-filled pressurized O_2 cylinders etc.) have to be dumped there during summers. Therefore, one has to be extremely cautious in the use of this limited resource. Electric supply is available at our location all the year, from a hydropower plant and high output diesel generators.

We carried out a review of available record of all medical and surgical cases treated in MST during the previous two years and evolved following two strategies:

1. To employ neuraxial and regional anesthesia techniques wherever possible
2. To procure an O_2 concentrator to confine use of O_2 cylinders

The O_2 concentrator (DeVilbiss®) was procured and was commissioned in September 2009. As it only requires constant electricity supply and uses atmospheric air as raw material, there is no running cost or logistics required for its continuous use. This study was carried out to ascertain the economy achieved by employing it and its impact on overall functionality of MST. Formal permission to carry out this study was obtained from the Advisor in Anesthesiology, the approval of Ethics Committee of the hospital and informed consent from the patients was also obtained for this study.

Due to high altitude location of MST, every patient undergoing surgery, under any kind of anesthesia technique required supplemental O_2 therapy peri - and postoperatively. The standard anesthesia technique (general/regional/neuroaxial etc) with basic monitoring (pulse oximetry (SpO_2), non-invasive blood pressure (NIBP) measurement, temperature and Electrocardiography (ECG) recording) was applied in all patients, who required anesthesia care. Supplemental O_2 therapy to every patient was provided through facemask from O_2 cylinders or portable O_2 concentrator.

A quasi experimental study was carried out form 1st October 2008 to 30th March 2010 to ascertain the efficacy of use of O_2 concentrator in our set up. All the patients requiring O_2 therapy during the above-mentioned period were included in the study selected by non-probability convenient sampling technique. The patients were divided into two main groups namely Group A (Cylinder Group) and B (Concentrator Group).

Group A (Cylinder Group) (n=53) comprised of all patients, regardless of the age and gender, who required O_2 therapy for any reason from 1 October 2008 to 30 March 2009. The data (sex, age, weight and height) were collected retrospectively from patient records. All the patients in group A were provided O_2 through O_2 cylinders. The number of cylinders consumed was also determined from the ledger record.

Group B (Concentrator Group) (n=81) included patients, of all age groups and both the sexes who required O_2 therapy for any. Their age, sex, weight and height were recorded and the patients were then categorized into two categories based upon the method used to provide O_2 i.e. via O_2 concentrator or cylinders. Cylinder consumption during period from 1 October 2009 to 30 March 2010, was then determined from the ledger record to calculate cylinder/patient ratio.

Statistical Analysis

All the data collected were entered into IBM SPSS v19.0® and simple comparative analysis was carried out by comparing the percentages of patients between group A and B with respect to use of O_2 concentrator vs. O_2 cylinder. The assessment of the economy achieved in the use of O_2 cylinders was done by comparing the cylinder/patient ratio of group A with that of group B. Percentage economy achieved was then calculated.

RESULTS

Patient Demography: In group A, male to female ratio was 8.8:1 whereas it was 9:1 in group B. Mean age of the patients was 37.47 ± 5.19 years and 36.34 ± 4.69 years in group A and B respectively. Mean height of the patients in group A was 170 ± 6.40 cm as compared to 171 ± 5.73 cm in group B. Mean weight of group A patients was 68 ± 4.20 kg while it was 70 ± 3.70 kg in group B.

Group A: All 53(100%) patients were provided O_2 therapy through O_2 cylinders, whenever required because no O_2 concentrator was available at that time.

Group B: The patients in concentrator group were divided into following sub-groups on the basis of posthoc analysis. Sub-group I (n= 9) included patients who were given neuraxial (spinal/ epidural) anesthesia for non gynaecological surgery. Sub-group II (n= 16) consisted of patients who underwent surgery under regional anesthesia (brachial plexus block/axillary block/popliteal block/bier's block etc) while sub-group III patients (n= 13) were operated under local infiltration anesthesia for minor surgeries. Sub-group IV (n= 5) consisted of female patients who were given spinal anesthesia for the caesarean section, sub-group V (n= 15) included patients who were given dissociative anesthesia (ketamine with sedation) for surgeries like change of dressing, manipulation of fractured limbs/ fingers etc. Sub-group VI (n=2) had patients who underwent emergency laparotomy under general anesthesia whereas sub-group VII (n=21) included patients who required O_2 therapy for treatment of high altitude diseases (acute mountain sickness, high altitude cerebral edema and high altitude pulmonary edema) and respiratory tract infections (moderate to severe pneumonia etc). Details of Group B (Concentrator group) patients (number/percentages) in each sub-group requiring O_2 through O_2 concentrator vs cylinder O_2 supply is shown in Table 1. Two patients of sub-group V and two of sub-group VI (total= 4, 4.93%) required general anesthesia, therefore cylinder O_2 supply was utilized in them. In group B, 95.07 % patients (n=77) requiring minor to major surgery were provided O_2 therapy with O_2 concentrator and only 4.93% patients (n=4), who required general/dissociative anesthesia consumed cylinder O_2 supply (Table 1).

Table 2: Comparison of consumption states of O_2 Cylinders with number of patients requiring O_2 therapy in group A and B. Table shows considerable economy achieved in the group B patients due to the use of O_2 concentrators.

Group/Period	No of Patients requiring O_2 Therapy (n)	Consumption of O_2 Cylinders (Numbers)	Cylinder/ Patient Ratio	Percentage Economy Achieved
Group A (from 01 October 2008 to 30 March 2009)	53	21	[21/53] 0.4	1333%
Group B (from 01 October 2009 to 30 Mar 2010)	81	3	[3/81] 0.03	

Cylinder/Patient Ratio and Economy Achieved: The use of O_2 concentrator proved extremely useful for our remote set up and enhanced its functional capability by manifold. In total three (E Type) O_2 cylinders were utilized by our set up in taking care of eighty one patients (n=81) of group B giving cylinder/patient ratio (3/81) "0.03". While last year twenty one (E type) O_2 cylinders had been consumed during the same period in taking care of fifty three patients (n=53) of group A , hence cylinder/patient ratio (21/53) was found to be "0.4" (Table 2). Comparing cylinder/patient ratios of both the groups, percentage economy achieved was calculated to be (0.4/0.03%) 1333% (Table 2).

Improvement in Functionality: Due to the availability of the extra gas supply and option to provide O_2 through O_2 concentrator during the surgeries requiring loco-regional anesthesia, overall functionality of the

Table 1: Comparison of different sub-groups of group B patients with respect to use of source of oxygen supply for O_2 supply from 1st October 2009 to 30 March 2010. 95.07% patients were provided O_2 through O_2 concentrator while only 4.93% used cylinder oxygen supply.

Group B (sub-groups)	Type of patients & anesthesia	No. of patients (n)	O_2 Concentrator Used* n (%)	O_2 Cylinder Used++ n (%)
Sub-group I	Non-gynecological surgery under neuraxial anesthesia	9	9 (11.11)	-
Sub-group II	Limb surgery under regional anesthesia	16	16 (19.75)	-
Sub-group III	Surgery under local infiltration anesthesia	13	13 (16.01)	-
Sub-group IV	Obstetric surgery under neuraxial anesthesia	5	5 (6.17)	-
Sub-group V	Minor surgery under dissociative (ketamine) anesthesia	15	13 (16.04)	2 (2.46)
Sub-group VI	Surgery under general anesthesia	2	-	2 (2.46)
Sub-group VII	Patients with medical or high altitude diseases	21	21 (25.92)	-
Total		**81**	**77 (95.07)**	**4 (4.93)**

*O_2 concentrator was used to give supplemental O_2

++ O_2 cylinder was used to provide O_2 through anaesthesia machine.

set up improved manifold as evident by increase in the number of patients who were operated/ treated providing O_2 therapy during 1st October 2009 to 30th March 2010.

DISCUSSION

The readiness of a military anesthesiologist for battle conditions must go beyond wearing uniform or being combat fit. True medical readiness implies that the anesthesiologists possess the skills and knowledge to provide anesthesia for any mission, anytime, anywhere.[8] To achieve this goal the anesthesiologist should be well conversant with the techniques that are "field friendly", requiring minimal logistical support while maintaining safety and providing quality anesthesia and analgesia.[9] The main problems which hinder the provision of quality care to any casualty in an austere environment are inadequate equipment, deficient or unavailability of pre-filled pressurized O_2 cylinders which are usually not transported by the air services, lack of facilities for equipment repair and hostile and adverse climatic conditions, inadequate or inappropriate accommodation, deficiency of blood and its products and transfusion facilities, inadequate monitoring equipment, delay in receiving the casualties due to inadequate or inappropriate evacuation facilities in unexpected or difficult terrain and loss of the golden hours and full stomach patients.[10] To allow safe surgery, intensive care and anesthesia of an acceptable standard in an austere environment there are some essential requirements which are shown in Box 1.

Box 1: Essential requirements for providing standard anesthesia and surgical care in field facing austere environments

Following are essential requirements for providing standard anesthesia and surgical care in field facing austere environments;

- Secure shelter at safe location
- Motivated doctors, paramedical and ancillary staff
- Ample supply of antibiotics, resuscitative medicines and dressing materials
- Satisfactory supply of electricity and arrangements of heating
- Availability of robust and quality surgical and anesthetic equipment and monitors
- Adequate supply of clean water
- Dependable medical gas supply

One item which deserves special attention because of its large logistic burden and importance is O_2. Venticinque SG et al in their recently published article have described O_2 as "Green Gold" and have opined that using as little "stuff" as possible and making use of all that you have, are self-evident principles when resources are limited and warrants little review.[5] O_2 conservation should be a priority because transporting gaseous O_2 is difficult business as a result of the cumbersome nature of the cylinders and has its own hazards.[5] Roberts MJ et al have categorically stated that reliance on pressurized O_2 cylinders is not entirely consistent with self sufficiency in many austere settings[11] while Gawande A et al have suggested initial solutions for forward medical teams which include carrying limited amounts of tank gaseous O_2 and using small, off-the-shelf, home-use portable O_2 concentrators.[12]

Due to its location and the mission assigned to it, our MST is peculiar. There is no road link available during the winters, so medical supplies, especially the medical gas cylinders, have always been a source of concern. To remain fully functional medical facility, a judicious use as well as conservation of resources is needed. Cylinders do provide 100% O_2 but are available in limited quantity, so there is always a possibility of shortage anytime but especially during the winters when replenishment is impossible. Remote and austere settings can pose significant challenges but choosing the right equipment, ingenuity, and sound professional skills can considerably improve the standard of care.

We rationalized the provision of general anesthesia and often successfully performed surgeries under neuraxial and regional anesthesia, whenever possible, which is consistent with the recent evidence. Many studies have shown, despite differences of opinion, regional anesthesia to be more 'field friendly' than general anesthesia.[7,13-15] There are numerous regional anaesthetic techniques which can be used in the field or field like circumstances e.g. in disasters, mass causalities or in austere environment.[9,14] These vary from topical applications or simple infiltration of local anaesthetics to major nerve conduction blocks or neuraxial blocks.[8,14]

Mechanism of O_2 concentrator: O_2 concentrators which use the principle of molecular sieve provide 93 ± 3% O_2 by separating the atmospheric air containing 21 % O_2 and 79% nitrogen. Nitrogen is adsorbed on aluminium silicate containing filters (Zeolite meshwork) through pressure swing adsorption (PSA) and almost pure O_2 is delivered either at low or high flow and pressure for medical use.[4,16]

Comparison of some of the characteristics of the O_2 concentrator and O_2 cylinder is shown in Table 3, highlighting suitability of the O_2 concentrator in disaster/warlike austere situations. Many studies have underscored the application of the O_2 concentrator in disasters and mass causality situations where all the infrastructure had been damaged due to natural disasters or war like situations.[17,18] There are reports showing successful use of O_2 concentrators in mass causalities due the earthquakes in Turkey, Iran and Pakistan; in tsunami affected areas of Indonesia; and hurricane Allison and Katrina afflicted areas of Houstan, Texas

Table 3: Comparison of the characteristics of Oxygen cylinders and oxygen concentrators [26, 27, 28]

Characteristics	Oxygen Concentrators*	Oxygen Cylinders
Capital cost	Not Much on portable selected models	High when regulator and flow-meter costs included
Running cost	Low if power is inexpensive High if power is expensive	High, particularly if leakage is significant
Ease of use	No considerable training required	Some training required
Reliability	Good	Good
Physical robustness	Good	Good
Regular maintenance	Not much (only air filter has to be changed after some duration)	Needed
Technical repairs	Needed	Needed (e.g. for regulators, to minimize leakage)
Electricity	Needed	Not needed
Continuity of O2 delivery	Good as long as power is available	Liable to run out
Portability	Very Good	Poor for large cylinders
Supply system	Once only Ordering needed Once only Transport needed Minimal Logistical arrangements required	Timely Ordering needed Transport needed Logistical arrangements for safe collection required (especially in remote areas)

* Portable O_2 Concentrator supplying 5-6 L/Min O_2

and New Orleans.[19-22] So much so, in some cases these concentrators had been successfully utilized for provision of general anesthesia where maintenance of anesthesia was done intravenously with midazolam/thiopentone sodium and ketamine and respiratory support was provided to the paralyzed patient through Ambu® bag attached to endotracheal tube whereas O_2 was supplied by O_2 concentrator.[7, 9, 23] Recently, an O_2 concentrator with the capability to compress O_2 into a cylinder has been developed (Invacare corporation, Elyria, OH; http://www.invacare.com).[24] This can give an anesthesiologist working in austere environment more options to provide standard level of care without worrying about the austerity and scarcity of medical gas supply.

The analysis of these experiences when extrapolated to our setting provided us ostensibly feasible option and has proved that way as well on the basis of our research. The availability of this equipment has relieved us of many apprehensions and enabled us to achieve a better standard of care. The economy achieved is been remarkable (1333%). The conservation of this precious resource has enabled us to undertake more and more surgeries at own location hence decreasing the evacuations to base hospitals, hence enhancing the functional capability of this set up by manifold. This has also decreased the demand for emergency aero-medical evacuations through helicopters, thereby minimizing the burden on the aviation set up of the area resultantly conserving the vital assets.

Recommendations: On the basis of above, following are highly recommended:

1. O_2 concentrator should be an essential part of equipment inventory for medical set ups meant for the remote areas and every emergency set up to be deployed in case of disaster situations. It will enable many clinicians to provide much improved standard of care in the field/operational settings
2. Anesthesiologists should have adequate training in the techniques of regional anesthesia and taught to employ these useful techniques to maximum during mass disaster situations or in austere environment

Limitations: Following limitations of my study are identified.

1. The study compared a retrospective data group with a prospective data group, this could have affected the results.
2. The anesthesiologist expertise in different regional anesthesia techniques can be a significant factor in the outcome of the study. So this has to be kept in mind.

CONCLUSION

War and other disasters, natural or manmade, will inevitably result in ailment and injury. The clinical specialists in warlike situations or disaster zones will always be challenged to provide advanced physiological support to preserve human life in these conditions. Given the mobility and modularity of modern medical systems, the ability to provide highest standard of care in the most austere circumstances has become not only a reality and periodic necessity, but an expectation. To discharge this responsibility in a befitting way, there is requirement of innovation, improvisation and judicious use of available resources in operational situations. Use of O_2 concentrator is one such measure which is evidence based, highly recommended and time tested. It provides very economical and easily applicable solution to O_2 shortage in resource limited austere environments.

Competing interests: We declare no competing financial, professional or personal interests that might have influenced the performance or presentation of this work described in this manuscript.

REFERENCES

1. Olasinde AA, Oluwadiya KS. Anesthesia Practice in a Hospital, developing countries: An 18 month's experience. The Intl J Third World Medicine 2005; 3; 1-4. (Free Full Text)
2. Roberts P, Patterns of injury in military operations. Current Anesthesia & Critical Care, Volume 13, Issue 5, October 2002, Pages 243-248. (Online Access)
3. Bonanno FG, Ketamine in war tropical surgery. Injury 2002; 33: 323 – 27. (Medline)
4. Litch JA, Bishop RA. Oxygen concentrators for the delivery of supplemental oxygen in remote high-altitude areas. Wilderness Environ Med 2000; 11: 189-91. (Medline)
5. Venticinque SG, Grathwohl KW. Critical care in the austere environment: Providing exceptional care in unusual places. Crit Care Med 2008; 36: S284-92. (Medline)
6. Grathwohl KW, Venticinque SG. Organizational characteristics of the austere intensive care unit: The evolution of military trauma and critical care medicine; applications for civilian medical care systems. Crit Care Med 2008; 36: S275-83. (Medline)
7. Dobson M, Peel D, Khallaf N. Field trial of oxygen concentrators in upper Egypt. Lancet 1996; 347: 1597-99. (Medline)
8. Grande CM, Baskett PJ, Donchine Y, Wiener M., Bernhard, WN, Trauma anesthesia for disasters. Anything, anytime, anywhere. Crit Care Clin 1991; 7: 339 – 61. (Medline)
9. McGuire NM, Monitoring in the Field. Br J Anaes 2006; 97: 46-56. (Medline) (Free Full Text)
10. Paix BR, Capps R, Neumeister G, Semple T. Anesthesia in disaster zone: a report on the experience of an Australian medical team in Banda Aceh following the 'Boxing Day Tsunami'. Anaesth Intensive Care 2005; 33: 629 –34. (Medline)
11. Roberts MJ, Salmon JB, Sadler PJ: The provision if intensive care and high dependency care in the field. J R Army Med Corps 2000; 146: 99–103. (Abstract) (Free Full Text)
12. Gawande A: Casualties of war - military care for the wounded from Iraq and Afghanistan. N Engl J Med 2004; 351:2471–475. (Medline) (Free Full Text)
13. Greengrass RA, Regional anesthesia for ambulatory surgery. Anesthesiol Clin North America 2000; 18: 341 –53. (Medline)
14. Klein SM, Evans H, Nielsen KC, Tucker MS, Warner DS, Steele SM. Peripheral nerve block techniques for ambulatory surgery. Anaesth Analg 2005; 101: 1663-75. (Medline) (Free Full Text)
15. Charuluxananan S. Bunburaphong P, Tuchinda L, vorapaluk P, Kyokong O. Anesthesia for Indian Ocean Tsunami –affected patients at a southern Thailand provincial hospital. Acta Anaesthesiol Scand 2006; 50: 320 –23. (Medline)
16. Dobson MB. Oxygen concentrators for the smaller hospital — a review. Trop Doct 1992; 22: 56-8. (Medline)
17. Schneider G. Oxygen supply in rural Africa: a personal experience. Int J Tuberc Lung Dis 2001; 5: 524-26. (Medline)
18. Shrestha BM, Singh BB, Gautam MP, Chand MB. The oxygen concentrator is a suitable alternative to oxygen cylinders in Nepal. Can J Anaesth 2002; 49: 8-12. (Medline)
19. Suzuki T, Difficulty in oxygen procurement in conflict or disaster areas. Masui 2009; 58: 508-13. (Medline)
20. Bar-Dayan Y, Leiba A, Beard P, et al: A multidisciplinary field hospital as a substitute for medical hospital care in the aftermath of an earthquake: The experience of the Israeli Defense Forces Field Hospital in Duzce, Turkey 1999. Prehosp Disaster Med 2005; 20: 103–06. (Medline)
21. Owens P, Forgione A, Briggs S: Challenges of international disaster relief: Use of a deployable rapid assembly shelter and surgical hospital. Disaster Manag Response 2005; 3: 11–16. (Medline)
22. D'Amore AR, Hardin CK: Air Force Expeditionary Medical Support Unit at the Houston floods: Use of a military model in civilian disaster response. Mil Med 2005; 170:103–108. (Medline)
23. Metcalfe NH, Military influence upon the development of anesthesia from the American Civil War (1861 – 1865) to the outbreak of the First World War. Anesthesia 2005; 60: 1213. (Medline)
24. McCormick BA, Eltringham RJ. Anesthesia equipment for resource-poor environments. Anesthesia 2007; 62: 54–60. (Medline)
25. Carter JA, Baskett PJF, Simpson PJ. The 'Permox' oxygen concentrator: its mode of action, performance and potential application. Anesthesia 1985; 40: 560-65. (Medline)
26. Howie SR, Hill SE, Peel D, Sanneh M, Njie M, Hill PC, et al. Beyond good intentions: lessons on equipment donation from an African hospital. Bull World Health Organ 2008; 86: 52-6. (Medline) (Free Full Text)
27. Wilson PM. Concentrators: portable and transportable. In: Portable oxygen: a user's perspective. Available online at http://www.portableoxygen.org/july.html. (Online Access)
28. Implementation of an oxygen concentrator system in district hospital paediatric wards throughout Malawi. Bulletin of the World Health Organization 2008; 86: 321-416. (Online Access)

★★★★★