*Thorax* 1993;48:1170–1177

*Pulmonary rehabilitation in chronic respiratory insufficiency · 4*

*Series editors: J-F Muir and D J Pierson*

# Long term domiciliary oxygen therapy in chronic obstructive pulmonary disease

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Chronic respiratory failure is a terminal event for many types of chronic respiratory disorder. Supplemental oxygen forms a fundamental part of treatment but its application is not easy and it has to be conducted for long periods of time. Long term oxygen will, of necessity, be given mostly in the home environment. It must be distinguished from short term oxygen administration for acute respiratory failure where the aims are quite different and intertwined more positively with mechanical ventilatory support.

Long term oxygen therapy (LTOT) utilises low dose supplementation of the inspired air to achieve an inspired oxygen concentration of approximately 30%. The figure was determined by early studies in chronic obstructive airways disease (COPD), the commonest cause of chronic respiratory failure.[1] Substantial elevation of arterial carbon dioxide tension ($PaCO_2$) had to be avoided. Higher oxygen concentrations interfered adversely with ventilatory control and ventilation/perfusion relationships in the lung. Subsequently, low dose techniques have been applied to all causes of chronic respiratory failure although this may not be appropriate optimal treatment in respiratory conditions where hypercapnia is not a problem.

## Aims of LTOT

Initial investigations into the use of LTOT tended to be by small, uncontrolled studies in patients with advanced hypoxic COPD. Typical of these were the studies by Neff and Petty[2] and Stark *et al.*[3] In the former, a reduction in haematocrit, pulmonary artery pressure (PAP) and oedema were found together with a reduced mortality compared with historical controls. In the latter, five patients with hypoxic COPD and pulmonary hypertension showed a significant reduction in PAP after 23–59 weeks of LTOT. This study also reported a reduction in residual volume, although other tests of lung function and arterial blood gases were unchanged. Morbidity was reduced as judged by a fall in number of acute admissions to hospital during the treatment period.

The results of these early studies suggested that the likely benefits of LTOT might include: (1) reduced mortality; (2) reduced morbidity and improvement of quality of life; and (3) improvement/stabilisation of abnormal physiological variables reflecting disease progression such as spirometry ($FEV_1$, FVC), lung volumes, residual volume (RV), total lung capcity (TLC), arterial blood gases ($PaO_2$, $PaCO_2$), haematocrit, PAP, and pulmonary vascular resistance (PVR).

The major controlled trials aimed to assess whether these goals were more universally attainable.

### REDUCTION IN MORTALITY

The only large, randomised, controlled study of LTOT is the British Medical Research Council trial (MRC trial).[4] Eighty seven patients with hypoxic COPD and at least one episode of peripheral oedema were randomised to receive standard medical treatment alone or the addition of oxygen given via nasal cannulae at a flow rate of 2 l/min for at least 15 hours/day. Mortality at three years was 45·2% in the oxygen treated group and 66·7% in controls. For the men there was no survival benefit until after 500 days of LTOT when the survival curves diverged. After this annual mortality was 12% in the treated group and 29% in controls. Women showed immediate survival benefit and annual mortality was 36·5% in controls and 5·7% in the treated group.

In the second major trial, the Nocturnal Oxygen Therapy Trial (NOTT),[5] 203 patients with hypoxic COPD were randomised to receive either "continuous" daily oxygen treatment (mean 17·7 hours/day) or 12 hours nocturnal treatment only. The entry criteria were similar to those of the MRC study but an episode of oedema was not essential and the patients had, on average, slightly less advanced airways disease. Follow up was for 12 or 24 months (mean 19·7). Mortality was 20·6% at 12 months and 40·8% at 24 months in those receiving 12 hours nocturnal treatment compared with 11·9% and 22·4% respectively in the group given "continuous" treatment. These differences were statistically significant.

Improvement in mortality over longer periods has not been shown in randomised, controlled studies. The poor prognosis of patients with hypoxic COPD with cor

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pulmonale has been documented in several papers.[6-8] In most series three year survival without oxygen is 32–53%, and five year survival 18–37%. These historical controls compare with predicted survival in the above studies of 50–68% and 32–53%, respectively, at three and five years.

Cooper *et al*[9] studied 72 patients having hypoxic COPD with cor pulmonale who received LTOT according to the MRC trial protocol for 12 years. Compared with historical controls, five year survival was 62% but at 10 years it was only 26%. No time lag before the onset of benefit in men was seen. This study implied a doubling of long term survival in comparison with historical controls. Ten year survival was disappointingly low.

Using the data from these studies, attempts have been made to identify subgroups expected to benefit most from LTOT. In the MRC study the 500 day period of equal mortality in men was interpreted as being due to some patients having disease so advanced as to be unsalvageable by LTOT. The test predictor of early mortality was a combination of raised $PaCO_2$ and red cell mass, but even this was poorly discriminating. The authors concluded that the most severely affected patients were less likely to benefit from LTOT and that early treatment should be instituted.

In the NOTT study those subgroups with a relatively higher $PaCO_2$, haematocrit, PAP, systemic acidosis, and lower FVC showed the most benefit from continuous treatment, suggesting that maximal benefit would occur in patients with at least moderately advanced disease. In a longer term follow up of patients in the NOTT trial, Timms *et al*[10] showed that a significant fall in PAP after six months of LTOT was associated with increased survival at eight years.

Another claimed predictor of mortality is the response of mean PAP to 24 hours oxygen therapy. Ashutosh and Dunsky[11] measured this in 43 patients with COPD commencing LTOT. A fall in PAP of more than 5 mm Hg was associated with a three year mortality of 30% compared with 90% in non-responders. In the study by Cooper *et al*[9] survival was significantly impaired in patients started on LTOT within two months of the first episode of oedema.

Nocturnal desaturation may be important to the pathogenesis and progression of pulmonary hypertension.[12] Carrol *et al*[13] studied 10 patients with COPD receiving LTOT who had a resting $Pao_2$ of >8 kPa during the day whilst receiving oxygen. Overnight oximetry showed that four patients had significant nocturnal desaturation despite concurrent oxygen therapy. It is possible that abolishing such desaturation may result in a further improvement in survival in patients treated with LTOT.

The effect of LTOT on mortality in other pulmonary disorders has hardly been studied. There are no large controlled trials, and these are urgently required. Zinman *et al*[14] performed a randomised controlled trial in 28 hypoxic patients with cystic fibrosis. No effect on mortality was seen after three years. Data from the Swedish oxygen register[15] show a three year survival of only 22% in hypoxic patients with interstitial lung disease but 62% in hypoxic patients after tuberculosis. The nature of the underlying disease responsible for respiratory failure is clearly important; survival benefit in fibrosing alveolitis would seem unlikely.

In summary, although there seems little doubt that LTOT is of benefit in patients with advanced hypoxic COPD, exactly how far advanced the disease needs to be for benefit to be seen is as yet unclear. Initiation of treatment at an early stage in advanced COPD seems to be important as mortality is extremely high despite LTOT in the most severely affected patients. Predictors of benefit such as changes in PAP are sufficiently interesting to require further confirmation.

## IMPROVEMENT IN QUALITY OF LIFE

Assessment of outcome other than by survival is difficult but is usually approached by subjective and/or objective tests of neuropsychological functioning, levels of emotional disturbance, activities of daily living, and exercise tolerance.[16]

A striking feature of most series is the very high level of emotional and mood disturbances in patients with COPD. For example, Boruk *et al*[17] found that, of 48 patients with severe hypoxic COPD receiving or who had been accepted for LTOT, only four had no evidence of depression and only two had a "normal" level of anxiety. Low self-esteem was universal.

Heaton *et al*[16] studied patients from the NOTT trial by means of neuropsychological testing, emotional status, and general quality of life. There was a significantly greater improvement in performance in the neuropsychological tests including simple sensory and motor ability, flexibility of thinking, and verbal/language functioning after six months oxygen treatment compared with the findings on retesting normal controls. These improvements were generally slight and relatively subtle, however, and ". . . did not constitute a major reversal of neuropsychological impairment in the patients with COPD." In the same study there was no evidence for LTOT causing a reduction in mood disturbance or emotional distress and no improvement in general quality of life. The authors argued that stabilisation might in itself represent a treatment success as a deterioration might have been expected to occur. No control data to support this contention were offered.

Lahdensuo *et al*[18] performed a similar analysis of 26 patients with severe COPD before and during LTOT for a six month period. Depression was reduced after treatment at a level approaching significance ($p < 0{\cdot}06$), but subjective and objective assessment of a range of activities of daily living and exercise tolerance showed no significant change.

In the MRC study[4] quality of life was not

specifically assessed. However, there were no significant differences in the number of days spent in hospital or at work in the treated and control groups. In contrast, Dilworth *et al*[19] studied 30 patients with mainly COPD who had recently been started on oxygen via an oxygen concentrator. Of these more than 80% reported considerable improvements in general wellbeing and breathlessness, and more than half in exercise tolerance and sleep pattern. Control measurements were again a problem.

Although widely prescribed for palliation, benefit from the use of oxygen in interstitial lung disease, cystic fibrosis, and malignancy has rarely been studied. Zinman *et al*[14] performed a randomised trial of nocturnal oxygen therapy in 28 patients with advanced cystic fibrosis. No significant differences were found between control and oxygen groups in exercise tolerance, psychological status, or hospitalisation. There was a significant decrease in attendance at work or school in the control group. In this study the treated patients received oxygen for a mean of seven hours/day.

Similar studies have not been carried out in patients with interstitial lung disease nor as palliation in terminally ill patients.

#### IMPROVEMENT/STABILISATION OF PHYSIOLOGICAL PARAMETERS

Early studies suggested that a reduction in morbidity and mortality would be achieved by preventing progression or even reversing the underlying disease process. Despite significant survival benefit, consistent improvements in physiological variables have been more difficult to demonstrate.

In the MRC study[4] surviving patients in the treatment and control groups showed no significant differences in spirometry measurements, arterial blood gas tensions, or haematocrit. There was a significant increase in PVR in the controls but not in the patients receiving LTOT, with a similar but smaller effect on PAP.

In the NOTT study[5] the only significant differences in physiological variables were a larger fall in haematocrit for the continuously treated group and a decrease in PVR compared with a slight increase in patients receiving nocturnal oxygen only. For both groups combined, the only significant changes were a fall in PVR and haematocrit after six months of treatment. The importance of these changes is unclear as, although patients with a high PVR and haematocrit had the highest mortality, the greatest benefit in increased survival was seen in patients with lower levels of PVR and haematocrit who had smaller falls in these values. There were no significant changes in mean PAP, spirometry indices, or arterial blood gas tension.

In the long term study by Cooper *et al*[8] there were no significant differences in mean PAP or PVR after 12 months of LTOT. Several patients were re-examined more than five years later and the stability of the pulmonary haemodynamics was confirmed. Death seemed more related to $FEV_1$ than to levels of blood gases or pulmonary vascular parameters.

Others have claimed a more dramatic response in physiological variables during LTOT, particularly Weitzenblum *et al*[20] who recorded changes in 24 patients with severe COPD in the period before (mean 53(41) months) and during (mean 44(30) months) LTOT. They found a significant slowing in the decline in $FEV_1$, a stabilisation of blood gas tensions, and a modest improvement in mean PAP during the period on LTOT compared with a steady worsening of all these values before commencement of treatment.

Other reports of dramatic improvements in patients receiving LTOT have tended to be confined to treatment periods of a few weeks only. For example, Gluskowski *et al*[21] showed an increase in $FEV_1$ and FVC, together with a significant fall in mean PAP and haematocrit, in patients after six weeks of LTOT.

In other diseases the evidence for changes in physiological variables during LTOT is much more scanty. The trial by Zinman *et al*[14] in patients with cystic fibrosis found no significant differences in spirometric values, arterial blood gases, or maximal oxygen uptake between controls and patients during LTOT.

There is thus some evidence that progression of pulmonary hypertension may be slowed, stopped or partially reversed by reductions in PVR. Evidence for improvements in other physiological variables is conflicting, but in most series a decline in $FEV_1$ continues inexorably. Even if reversal of pulmonary hypertension is confirmed, its relevance in terms of survival is not yet clear. Most of the evidence for improvements in physiological variables comes from longitudinal studies with patients acting as their own controls or by comparison with historical controls. Randomised, controlled studies are rare.

In summary LTOT has only been shown to achieve the aim of reduced mortality in patients with advanced hypoxic COPD. Evidence for beneficial effects on quality of life and physiological parameters is scanty. The effect of increased survival has been sufficient to ensure the widespread adoption of LTOT for patients fulfilling the entry criteria. Progress with LTOT may come from a more accurate definition of those groups most likely to benefit, and a better definition of benefit other than survival. In other conditions there is an urgent need for good clinical trials to assess the effectiveness of LTOT in palliation and reducing mortality.

## Criteria for LTOT

#### CURRENT ADMISSION CRITERIA

The criteria used to select patients suitable for LTOT are based on the two major trials[4,5] and can be summarised as follows. Non-smoking patients with stable, severe obstructive pulmonary disease ($FEV_1 < 1{\cdot}5$ l) and arterial hypoxaemia ($Pa_{O_2} < 7{\cdot}3$ kPa

[55 mm Hg]) with or without hypercapnia may benefit from the prescription of low flow domiciliary oxygen used in excess of 15 hours/day. These criteria have been chosen for the following reasons.

*Arterial hypoxaemia*
The main indication for LTOT in patients with COPD is an arterial oxygen tension <7·3 kPa (55 mm Hg). This figure was selected as it marks the point on the oxyhaemoglobin dissociation curve where a significant reduction in oxygen delivery to the tissues begins to occur and further small decreases in arterial $Pa_{O_2}$ result in significant increases in tissue hypoxia.

*Spirometry*
Spirometric analysis is an essential part of patient selection for several reasons; firstly, to confirm an obstructive disorder as the aetiology of the hypoxaemia rather than interstitial lung disease for which there is no controlled trial benefit of LTOT, and secondly, since LTOT does not halt the progressive decline in lung function or resting arterial hypoxaemia it is unlikely that patients with a very low $FEV_1$ (<0·6 l) will benefit as much. An $FEV_1$ <1·5 l and FVC <2 l indicate relatively severe COPD, but not severe enough to make the use of LTOT unlikely to improve survival.

*Disease stability*
The importance of ensuring disease stability before prescribing domiciliary oxygen has been shown both in the NOTT study[5] and by Levi-Valensi *et al*[22] who found that, over a three month stabilisation period following an acute exacerbation of COPD, approximately 30% of patients improved their arterial oxygen tensions merely by optimising medical management to the extent that they no longer fulfilled the selection criteria for LTOT. For this reason both arterial hypoxaemia and spirometric values should be retested after an interval of at least three weeks, and perhaps up to three months after an acute exacerbation, to ensure stability. A variation of over 20% in spirometric values and a 0·6 kPa (5 mm Hg) variation in arterial hypoxaemia suggests instability and the need for continued observation rather than immediate oxygen prescription.

*Oedema formation*
Oedema is an easily recognisable clinical marker of cor pulmonale and of a clearly defined stage in the evolution of COPD. It was used as an entry criterion in the MRC trial[4] as it was thought to delineate a group likely to benefit from supplemental oxygen. Its one main disadvantage as a criterion is the link with a poor prognosis (67% five year mortality in the untreated group of the MRC trial).

*Non-smoking*
Continued cigarette smoking in patients on domiciliary oxygen not only poses a significant fire hazard but has also been shown to attenuate its benefits.[23] In some countries carboxyhaemoglobin levels are measured to assess compliance with cessation of smoking before installation of an oxygen concentrator.

## CURRENT INDICATIONS IN THE UK

These fall into three categories[24]: (1) absolute (hypoxaemic COPD with $Pa_{O_2}$ <7·3 kPa (55 mm Hg), $Pa_{CO_2}$ >6·0 kPa (45 mm Hg), oedema likely, $FEV_1$ <1·5 l, FVC <2·0 l); (2) relative (as in (1) but without oedema or hypercapnia); and (3) terminal (respiratory failure from any cause).

While these three indications are also used in the USA,[25] a fourth group of patients is included with $Pa_{O_2}$ of 7·3–8·0 kPa, (55–60 mm Hg), with either elevated haematocrit, elevated PAP, or evidence of cor pulmonale ("P" pulmonale on ECG or oedema). Relatively few studies have been performed to support the use of the latter criteria. The indications are based on physiological considerations and anecdotal clinical evidence. For example, whilst the severity of polycythaemia (an indicator of tissue hypoxia) may be related to severity of the underlying chest disease and, as such, may have prognostic implications, LTOT results in only slight falls in haematocrit.[5] On the other hand, pulmonary artery hypertension worsens prognosis[26] and those patients with the best reduction in PAP on LTOT benefit the most in terms of survival.[5]

## INTERCOUNTRY VARIATION IN SELECTION CRITERIA

Minor physiological differences between the groups of patients in the MRC and NOTT trials account for some of the differences in the indications and physiological parameters measured before the prescription of LTOT in the UK and the USA.

## CURRENT ISSUES IN LTOT CRITERIA

*Nocturnal oxygen desaturation*
Nocturnal oxygen desaturation may occur through two separate mechanisms in patients with COPD: (1) obstructive sleep apnoeas, and (2) non-apnoeic REM sleep desaturations. In many cases there is a degree of overlap. Some patients with COPD without significant daytime arterial hypoxaemia (< 8·0 kPa (60 mm Hg)) have nocturnal hypoxaemia[12 27] and some also have polycythaemia, right ventricular hypertrophy, and hypercapnia which may benefit from LTOT. Evidence suggests that episodes of REM sleep associated desaturation below 85% cause no clinical harm but are currently thought to be important in the evolution of the above parameters. This is being studied further to determine the effectiveness of LTOT in the prevention of their progression but no definite benefit has yet been shown. Obstructive sleep apnoeas are more appropriately treated by nasal CPAP and medical measures such as oxygen alone, although reducing desaturation may increase the number of apnoeic episodes.

*Exercise induced hypoxaemia*
Some relatively normoxaemic as well as hypoxaemic patients become profoundly hypoxaemic during exercise[28] but at present there is no evidence that LTOT provides long term benefit.

*Ambulatory oxygen*
Ambulatory oxygen is the provision of oxygen during walking. It is given to reduce effort induced breathlessness, extend walking distance, and permit greater use of oxygen supplementation than can be provided by static sources. The oxygen may be provided through nasal cannulae or transtracheal catheters from small portable rechargeable cylinders or by a small liquid oxygen unit filled from a liquid storage unit at flow rates of about 4 l/min.[29]

There are great disputes between the USA and Europe as to efficacy of ambulatory oxygen. In the USA any hypoxaemic individual with respiratory disease or who desaturates on exercise is claimed to benefit. Few double blind studies have been conducted. In Europe only 25% of such individuals were found to have clear benefit judged by reduced breathlessness and extended walking distance.[30-32] Liquid portable systems are preferred to gas cylinders by those showing clear benefit, but liquid oxygen is generally more expensive than concentrator oxygen. There is no indication for the widespread use of liquid oxygen for LTOT to serve the few who clearly benefit during ambulation. Special arrangements for the latter should be made.

## CURRENT USAGE OF LTOT FOR COPD IN THE UK

The volume of oxygen supplied to patients at home increased fourfold between 1985 and 1989[33] but, despite this, a significant number of patients eligible for LTOT do not receive it as shown by a 1985 community survey in Sheffield.[34] Of approximately 600 patients eligible for an oxygen concentrator in Sheffield only about 70 had been prescribed it, indicating a large population of possibly undertreated patients. In contrast, despite the strict entry criteria, a Liverpool study of general practice[35] found that only 32 of 62 patients fulfilled the criteria and in 30 of the 62 cases LTOT had been prescribed for an inadequate time—that is, less than 15 hours/day—emphasising that underusage is often secondary to poor prescribing rather than poor compliance. In a more recent study[36] 82% of patients prescribed LTOT by hospital respiratory physicians fulfilled the criteria compared with 33% of patients prescribed by general practitioners or non-specialist physicians, indicating that a significant proportion of LTOT is being prescribed without adequate assessment. In Poland the problem of inappropriate prescription of LTOT is negligible[37] as LTOT can only be prescibed by a respiratory physician, again indicating the value of appropriate appraisal.

Domiciliary oxygen consumption is increasing annually, yet oxygen concentrators do not appear to be substituting the use of cylinders to any great extent despite the fact that concentrators would be more appropriate in many cases. This in itself presents a considerable financial burden to the National Health Service.[33] It begs the question as to why so many patients are prescribed just a few cylinders per week.

In summary, domiciliary oxygen appears to be underprescribed for appropriate cases, and in those to whom it is prescribed it is often inappropriate and for inadequate durations. The correction of these ongoing deficiencies should clearly lie with the education of those prescribing, appropriate assessment by respiratory physicians before any prescription is made, and careful monitoring thereafter.

## SPECIAL SITUATIONS

*Lung fibrosis*
There are, as yet, no randomised trials to prove the efficacy of LTOT in altering mortality in patients with lung fibrosis. The death rate in many forms of hypoxic lung fibrosis is depressingly high.[15] Oxygen may palliate dyspnoea and fatigue and it may be appropriate to prescribe oxygen for this reason to patients with end stage interstitial lung disease. Assessments of benefit will clearly have to extend beyond survival. High oxygen flow rates are often required to correct hypoxaemia and larger concentrators or two concentrators in tandem may be required.

*Cystic fibrosis*
A randomised trial of nocturnal oxygen[14] did not affect either mortality rates, frequency of hospitalisation or disease progression in those cystic fibrosis patients having daytime $Pa_{O_2}$ <7·3 kPa, and hence it is unlikely to be important in the long term management of cystic fibrosis.

## OTHER CONSIDERATIONS TO THE INTRODUCTION OF LTOT

Besides satisfying the physiological criteria, there are other important factors to be considered before prescription of LTOT is made. LTOT confers a considerable burden to both the patient and his immediate family. Their commitment and likely compliance with treatment should be carefully assessed. The fact that LTOT is used for 15 hours/day or more should be clearly conveyed to the patient, and it should be emphasised that LTOT is not for symptomatic short burst relief of dyspnoea.[38] Dyspnoea should not be equated with hypoxaemia.

## HOME CARE SUPPORT AND MONITORING

LTOT is only one component of a comprehensive rehabilitation programme of home care for the chronic respiratory disabled patient. Monitoring of progress with spirometry and pulse oximetry are part of the package. Exercise rehabilitation, nutritional

advice, physiotherapy, psychosocial support for patient and family care givers, and institutional assessment are other components. Trained respiratory care personnel should implement the service either through a broader domiciliary nursing or independent service. Equipment supply and maintenance can be provided by private contracting companies or state purchasing authorities. The use of private contractors to provide equipment and its maintenance through a rental scheme has proved successful in the UK.

## Equipment for LTOT

There are three ways of providing oxygen in the home: (1) compressed into a cylinder; (2) an oxygen concentrator; and (3) in liquid reservoirs.

### CYLINDERS

Cylinders have been in existence since 1888. Originally made of heavy carbon steel, they are now supplied in light weight aluminium for domiciliary use. The size most commonly used in England is "F", holding 1360 l at 2000 psi, supplying 2 l/min oxygen for 10 hours from one cylinder. A regulating head must be fitted to the cylinder. The general practitioner may prescribe cylinders and a simple reducing valve and mask to give 2 l/min at the "medium" setting and 4 l/min at the "high" setting. No intermediates are possible. If the patient needs a more accurately controlled flowmeter or nasal cannulae, these must be supplied extra to the prescription. Portable cylinders may be filled from this stationary source, but have to be provided through the local hospital. The gas expands as it leaves the cylinder to feel cold to the patient. Many patients find this reassuring. Similar arrangements are available in many countries, but with less restrictive flow rates.

### OXYGEN CONCENTRATORS

These machines have been commercially available for domiciliary use since 1974 and prescribable by general practitioners in the UK since 1985. Electrically powered, the concentrator takes oxygen from ambient air through two chambers containing a zeolite, a substance which allows oxygen to pass through when the gas in the chamber is compressed. Two "molecular sieves" are used cyclically, allowing an uninterrupted supply of oxygen from 0·5 to 4 l/min. The lower flow rates provide the highest concentrations of oxygen. In the UK the supplying company installs and maintains the machines, pays for the electricity used, and provides mask or nasal cannulae as requested. At the moment it is not possible to fill a portable supply from this system. The supply is at room temperature so patients are less aware of the sensation of receiving the treatment. They are relatively cheap to provide and maintain. Many countries have similar arrangements but the equipment is provided through alternative state or insurance organisations.

### LIQUID RESERVOIRS

Containers like large vaccuum flasks are installed at the patient's home and filled with liquid oxygen on a regular visit by the supplier. Flow rates from 0·25 to 8 l/min are possible. The patients may also fill a portable system from the stationary supply. This system is not available in the UK at this time. Current costs are double those of a concentrator installation because of delivery expenses. There are advantages when high flow rates or a portable system are necessary. The system must be used regularly. Oxygen is vented continuously as a means of maintaining the remaining gas liquid.

The use of liquid oxygen varies from one country to another, none being used in the UK to more extensive use in USA, France, Italy and Germany.

### CANNULAE AND MASKS

There are several methods of patient-oxygen interface in current use.

Oxygen is supplied on a continuous basis. Nasal cannulae made of polyvinylchloride with proximal twin prongs to introduce gas to the nostrils are most commonly used.[39] There are few complications in practice; they keep a reasonably stable position, and nasal irritation and mucosal drying are the commonest complaints. Some patients prefer masks, believing there is more benefit, particularly if they suffer from congested or blocked nostrils or are known mouth breathers. They must be carefully selected to give 28–32% oxygen at the face.[40 41] In general masks are cumbersome and do not allow for usual eating, thinking, talking, or the wearing of spectacles. Masks are available to fit over tracheostomy tubes. When masks or cannulae are selected, the arterial blood gases achieved must be checked periodically.

### HUMIDIFIERS

A humidifier attached to the oxygen source flowmeter may be supplied if nasal drying is a problem. It is usually unnecessary at flow rates between 1·5 and 2·5 l/min. Regular changing of sterile water and scrupulous hygiene must be maintained if humidification is used.

### OXYGEN CONSERVATION DEVICES

Oxygen flows only during inspiration, making the supply last longer. Reservoir devices aim to fill a small chamber in the cannula at flow rates of 0·5–1·0 l/min from the source, which is then available as a bolus when the patient first inspires. The reservoir chamber is placed under the nostrils or on a pendant resting on the chest. These devices are not widely used despite potential oxygen saving.[42]

### DEMAND OXYGEN DELIVERY SYSTEMS

In these systems an electronic device senses inspiratory effort, delivering the correct flow of oxygen only during inspiration. The patient must be close to the source and humidification is debarred. Monitoring devices to measure gas usage can be added.[43]

TRANSTRACHEAL OXYGEN THERAPY

This is available throughout the world in specialist centres. A transcutaneous tracheal fistula is fashioned surgically through which a small cannula is inserted. Oxygen flow rate requirements are halved compared with nasal cannulae. A high level of patient education is required to keep the device clean and patent. Complications such as mucus ball formation, tracheal haemorrhage, and infection can be troublesome to the uninitiated.[44]

It is also possible to tunnel under the skin from the lateral thorax to enable the catheter to be inserted into the cervical trachea. These devices are considered more socially acceptable but few physicians allow such views to take precedence over the invasive nature of the procedure. It is also possible to supply transtracheal oxygen by a phased delivery system to allow full 24 hour oxygen for an ambulant patient. The equipment weighs 5 kg which is something of a limitation. Improved patient compliance is claimed.

## Future of LTOT

Increased effectiveness of low flow oxygen, more effective home care support, and better monitoring of treatment are the three most important current issues.

Low flow oxygen improves survival in hypoxaemic patients with COPD but does not influence the natural decline of airway function or $PaO_2$. Better oxygenation is being approached in two ways—through additional pharmaceutical means, or through non-invasive ventilatory support. Almitrine bismesylate, a chemoreceptor agonist, improves $PaO_2$ by an average of 1 kPa (7·5 mm Hg) above that achieved by LTOT. Side effects were a problem in early studies but are more acceptable in recent studies with lower doses.[45] Studies have still to be conducted for sufficient time to elicit survival benefits.

The issue of ventilatory support will be considered in other articles of this series.

Extension of LTOT to other diseases is debatable. Most physicians draw parallels with COPD for other causes of respiratory failure and treat accordingly. Definitive studies are yet to be performed. As the underlying mechanisms of respiratory failure differ in different diseases, caution should be exercised. Better methods of assessment other than survival are required; quality of life questionnaires being studied by a number of groups are a step in the right direction.

LTOT is but one component of long term respiratory care. Home care teams supporting family carers are still poorly developed in most countries. Monitoring of treatment in the home is rarely performed on a regular basis. Most countries rely on problem solving rather than preventive monitoring.


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