Published in final edited form as:

Curr Opin Anaesthesiol. 2011 February ; 24(1): 44–48. doi:10.1097/ACO.0b013e3283420608.

Lung volume reduction surgery: non-pharmacological approach

Roberto Benzo, MD MSc [Senior Associate Consultant]

Division of Pulmonary & Critical Care Mayo Clinic 200 First ST. SW Gonda 18-440 Rochester MN 55902 benzo.roberto@mayo.edu

Abstract

Purpose of review—This review aims to revise the current nonpharmacologic methods used in the care of patients undergoing Lung Volume Reduction Surgery (LVRS)

Recent findings—A recent report of the unquestionable palliative role of LVRS awakened a renewed interest in the procedure as a valid treatment alternative in selected patients with severe emphysema.

Summary—A detailed description of the foundations of the approach to patients undergoing LVRS is described to provide guidance for daily practice.

Keywords

COPD; Lung Volume Reduction; Pulmonary Rehabilitation; Self efficacy; Physical Activity

Introduction

Lung Volume Reduction Surgery (LVRS) meaningfully improves quality of life in properly selected patients with severe emphysema (patients with upper lobe predominant disease) and also survival in a subset of them[1]. The unquestionable clinical significance and palliative effect of this procedure has been recently addressed in the literature[2] and is the spirit of this short review.

The care of patients undergoing LVRS requires a complete understanding of the pathophysiology of severe chronic obstructive pulmonary disease, the planned surgical procedure, and the anticipated postoperative course for this group of patients.

Preoperative care for patients undergoing LVRS sits on two critical pillars: the proper selection of the candidate and a comprehensive pulmonary rehabilitation primarily oriented to increase physical activity and patient's self efficacy for dealing with symptoms (mainly dyspnea, anxiety, and fatigue)[3]. Risk factors for morbidity and mortality from this surgery come from the results of the National Emphysema Treatment Trial (NETT), the world's largest multi-center, a randomized trial comparing LVRS to maximal medical therapy, set a strong foundation for risk assessment before thoracic resection in severe COPD patients[1, 4-6].

General anesthesia, positive-pressure ventilation and one-lung ventilation (OLV) in patients with emphysema and severe airflow obstruction are a challenge since they can lead to severe gas trapping, dynamic hyperinflation and hemodynamic consequences [7].

Post operative care key factors include early extubation, minimizing the potential for a prolonged air leak, a careful pain control, the management of respiratory failure and early ambulation[8].

1-LVRS Preoperative Care

Preoperative care roots in proper patient selection and specialized pulmonary rehabilitation.

1a-Patient Selection

LVRS should be considered only in severe emphysema after patients have undergone optimal medical treatment, including pulmonary rehabilitation, and fail to improve their clinical status[2, 3].

Pulmonary Rehabilitation showed to be critical adjunct to medical treatment that substantial number of NETT candidates reported an improvement in their symptoms after pulmonary rehabilitation that was so significant that they withdrew their consent to undergo LVRS if randomized to treatment.

NETT demonstrated that patients with upper lobe–predominant emphysema on chest CT benefited from LVRS in terms of improvements in lung function, exercise performance, quality of life, and a reduction in patient symptoms[1]. The latter highlights the value of assessing the severity and distribution of emphysema from High Resolution chest CT images. Patients with upper lobe–predominant emphysema and a low maximal workload on cardiopulmonary exercise testing also had a significant survival advantage with LVRS compared with optimal medical management, a finding that remains preserved in long-term follow-up[9].

One of the most useful and practical lessons from NETT, as it can be translated in the evaluation for lung resection in general, has been the definition of patients with unacceptable **high operative risk**, 30-day mortality rate of 16%[10], in patients with FEV₁ 20% predicted and either homogeneous emphysema or diffusing capacity of carbon monoxide [DL_{CO}] 20% predicted. NETT also reported an operative mortality rate (deceased within 90 d of LVRS) of 5.5% and a major pulmonary morbidity rate of 29.5%[11].

Naunheim and colleagues [11] analyzed risk factors for operative morbidity and mortality in the patients in the NETT after excluding those found on interim analysis to be at high operative risk of death after LVRS. In non-high risk patients, age, FEV₁, and DL_{CO} were found to be risk factors for major pulmonary morbidity, defined as tracheostomy, failure to wean from mechanical ventilation, reintubation, pneumonia, and mechanical ventilation for 3 days or longer. In contrast to earlier literature, the analysis of NETT data did not reveal hypercapnia or poor exercise tolerance to be predictors of worse outcome. This may reflect trial design, with the intentional exclusion of those with a PaCO₂ greater than 60 mm Hg (55 mm Hg in Denver) and a six-minute-walk distance of 140 m or less[1]. Interestingly, a non–upper lobe–predominant distribution of emphysema did not increase the risk for PPC, but did increase operative mortality (relative odds, 2.99; $P = 0.009$) and cardiovascular morbidity (relative odds, 2.67; $P < 0.001$). Careful assessment for cardiac disease before selection for LVRS is also necessary as a high prevalence of coexistent coronary artery disease exists in chronic obstructive pulmonary disease (COPD). A pharmacologic stress test is recommended to screen for occult cardiac ischemia to attain heart rates that definitively exclude cardiac ischemia. If clinical suspicion is high, and/or a pharmacologic stress test is equivocal or submaximal, coronary angiography should be considered. Patients should maintain at least 4-month abstinence from cigarette smoking before surgery.

1b-Pulmonary Rehabilitation

Pulmonary rehabilitation is a critical part of patient preparation before LVRS and its main aim is to increase the self efficacy for controlling symptoms and for physical activity. The

latter, not only increase patients' endurance but also facilitates the willingness for an early ambulation after surgery. The prescription of exercise during the rehabilitation session should follow the current guidelines[12, 13], however special attention should be paid to the physical activity outside the pulmonary rehabilitation laboratory. A collaborative, empathic approach of the patient, setting goals of activity between sessions, fostering patient autonomy and obeying patient preferences is most likely the way to make the patient adopt a more active lifestyle that will likely translate into a better outcome[14].

Improving patient's anxiety in the context of dyspnea is another important goal that is usually accomplished through increased self-efficacy to deal with that symptom. Modeling (seeing and interacting with other patients and learning from them in the context of PR), practicing breathing (mainly slow breathing with pursed lips) stretching and endurance exercises together with disease education tailored to what the individual patient needs are key to improve perception of anxiety and stress in front of symptoms[15].

Establishing a *practice* of slow pursed lips breathing during the period of Pulmonary Rehabilitation is almost universally referred by patients as a part of their rehabilitation as the decrease their dyspnea and promote relaxation and calmness. The latter becomes very important in the immediate post operative period when promoting calmness is necessary to deal with dyspnea, pain and mixed emotions that invariable appear without the use of pharmacy. The word *practice* in this context indicates devoting time daily to do slow pursed lips breathing without any distraction (tv, radio, reading) devoted just to concentrate on their breath. In our Institution we recommend at least 15 minutes a day, and even during their time using the nebulizer. In addition slow breathing is known to decrease hyperinflation, sympathetic tone and cardiovascular stress[16-18].

The use of inspiratory muscle training, not routinely recommended in pulmonary rehabilitation[13] has a place in preoperative pulmonary rehabilitation given recent strong evidence that reported its beneficial effect during the preoperative phase by decreasing pulmonary complications after thoracic surgery[19]. We conducted a randomized controlled trial of PR before lung resection in COPD that included inspiratory muscle training with clinically significant results. We adopted inspiratory muscle training at our Institution in the pre operative Pulmonary Rehabilitation of thoracic resections included LVRS.

The rapid identification and treatment of exacerbation is an important topic in PR as exacerbation is one of the main reasons for missing PR sessions particular in severe patient in whom the prevalence is greater as recently reported from the ECLIPSE study[20]. The education on the use of an emergency plan for exacerbations: self use antibiotic and prednisone with detailed orders, has been reported beneficial in several trials[21, 22].

Postponement of surgery should be considered if the patient is considered not at their baseline health status (particularly dyspnea status) or if a respiratory tract infection or COPD exacerbation is present.

Finally and importantly, awakening a spirit of resilience and promotion of calmness to face the procedure has been in our experience an important asset for success.

2-LVRS Intraoperative considerations

A patient that gained self efficacy to control his/her symptoms during the pre operative pulmonary rehabilitation is more likely to be more calm and cooperative, making sedative premedication unnecessary[23]. Even when small doses of a benzodiazepine may be beneficial for those treated chronically with benzodiazepines, a sedative/hypnotic agent may delay extubation at the conclusion of surgery. {Brister, 2008 #707}

Hypotension can occur at any time during the procedure and is most commonly seen upon induction of anesthesia. Dynamic hyperinflation (air-trapping, auto-PEEP), that reflects the severity of the airway disease, can occur with either hand ventilation or upon conversion to mechanical ventilation is usually the cause of hypotension. Disconnecting the ventilator circuit from the endotracheal tube leads to a rapid resolution of hypotension if this is the etiology. Sympathetic blockade from a thoracic epidural catheter, pneumothorax or the vasodilatory effects of induction agents may be other causes of hypotension. An arterial line facilitates beat-by-beat hemodynamic monitoring since administration of vasoactive agents may be necessary and also facilitates repetitive blood gas sampling. A Pulmonary Artery catheter use is not recommended.

Intra-operative ventilator management is directed toward producing adequate oxygenation with a low tidal volume technique while maximizing exhalation time to prevent dynamic hyperinflation and to minimize the likelihood of disruption of suture lines or of the adjacent non-resected lung tissue. Both pressure-controlled and volume-controlled ventilation with the measuring of auto-PEEP have been used to successfully achieve these goals.

Hypercapnia is the most common result of the low tidal volume ventilation strategy; however most patients tolerate elevated CO₂ levels well during surgery. When pH falls below 7.2, maneuvers need to be instituted to increase minute ventilation[24]: increase the rate of ventilation, while remaining mindful of the risk of increased auto-PEEP.

Oxygenation is often easily maintained by prudent monitoring of inspired oxygen; secretions, adequate muscle relaxation, and aggressive treatment of any bronchospasm. Due to decreased elastic recoil, deflation of the operative lung is prolonged during one lung ventilation in this patient population. The more diseased portions of the lung will deflate more slowly than the more normal parenchyma and may assist the surgeon in identifying targets for resection.

A good pain control is a necessary component of the anesthetic plan for LVRS. An epidural infusion is a prevalent pain management strategy, but multimodality approach combining regional techniques with parenteral agents is more widely accepted. Careful use of narcotics in patients with baseline hypercapnia is mandatory as may decrease the chance of a rapid extubation after surgery.

3-LVRS Post operative care

Post operative care in LVRS aims to four specific actions: early extubation, the treatment of air leaks and respiratory failure and early ambulation.

3a- Early Extubation

Extubation at the conclusion of surgery is dependent on the absence of significant bronchospasm, secretions, hypercapnia, or acidosis. Patients with hypercapnia may still be extubated if other criteria are acceptable. Frequent or continual nebulization of bronchodilators is essential with the patient in a head-up position. If serial blood gases reveal progressive hypercapnia, noninvasive ventilatory support may be used to stabilize gas exchange and decrease the work of breathing while further investigation proceeds.

3b- Air Leaks

In contrast to lung resection for lung cancer, the majority of patients undergoing LVRS have an air leak during the postoperative period. In the NETT, 496 of 552 (90%) patients experienced air leak at some time in the first 30 days after LVRS[4]. DeCamp and colleagues [4] reported that patients with a predominantly lower lobe distribution of emphysema had fewer air leaks than patients with other emphysema distribution. In

addition, a low diffusing capacity and the presence of marked adhesions were strongly associated with the occurrence of air leak.

The practice at our Institution has been to place the chest tubes to water-seal rather than suction as the current evidence suggest that as the best practice in patient with underlying severe emphysema [25].

3c- Postoperative Respiratory Failure

Minimized use of narcotic analgesics, appropriate and early use of antibiotics, and early mobilization will all help to minimize the incidence of respiratory failure. The routine use of noninvasive ventilation has been implemented at some centers in the immediate postoperative period to prevent hypoventilation, atelectasis, and hypoxia.

If respiratory infection is suspected, use of antibiotics should not be delayed. The choice of antibiotic agent should be focusing to the organisms prevalent this population (*Haemophilus* and gram-negative bacilli). Once microbiologic data are available identifying an organism and antibiotic sensitivities, therapy should be promptly narrowed and a predetermined stop date set.

3d- Early Mobilization

Early postoperative mobilization after LVRS should be instituted whenever feasible to help reduce the incidence of atelectasis, minimize use of narcotic analgesics, reduce recovery time, improve mood and prevent muscle atrophy.

CONCLUSIONS

Lung volume reduction surgery (LVRS) remains the most effective way of lung reduction in emphysema. Several non surgical methods that are the matter of current and extensive research for the best approach since none of them have not shown the degree of efficacy attained by the surgical procedure. LVRS provides a durable palliation of dyspnea in appropriately selected patients with moderate to severe emphysema. Appropriate patient selection and preoperative preparation are prerequisites for successful LVRS. An effective LVRS program critically requires participation and communication between experts from different disciplines: pulmonary medicine, thoracic surgery, thoracic anesthesiology, critical care medicine, rehabilitation medicine, respiratory therapy, chest radiology, nursing, and the patient (an expert of living with emphysema).

Acknowledgments

Dr. Benzo is funded by Grant# 7K23CA106544-02 from the National Institutes of Health. Unites States of America

References

- 1**. Fishman A, Martinez F, Naunheim K, Piantadosi S, Wise R, Ries A, et al. A randomized trial comparing lung-volume-reduction surgery with medical therapy for severe emphysema. *The New England journal of medicine*. May 22; 2003 348(21):2059–73. [PubMed: 12759479] [Outstanding evidence and reviews on LVRS worth reading for more in depth details of every phase of LVRS care.]
- 2*. Benzo R, Farrell MH, Chang CC, Martinez FJ, Kaplan R, Reilly J, et al. Integrating health status and survival data: the palliative effect of lung volume reduction surgery. *American journal of respiratory and critical care medicine*. Aug 1; 2009 180(3):239–46. [PubMed: 19483114] [This manuscript emphasizes the real palliative effect of LVRS that is worth considering in patients with poor quality of life due to emphysema.]

- 3**. Criner GJ, Sternberg AL. A clinician's guide to the use of lung volume reduction surgery. *Proceedings of the American Thoracic Society*. May 1; 2008 5(4):461–7. [PubMed: 18453356] [Outstanding evidence and reviews on LVRS worth reading for more in depth details of every phase of LVRS care.]
4. DeCamp MM, Blackstone EH, Naunheim KS, Krasna MJ, Wood DE, Meli YM, et al. Patient and surgical factors influencing air leak after lung volume reduction surgery: lessons learned from the National Emphysema Treatment Trial. *Ann Thorac Surg*. Jul; 2006 82(1):197–206. discussion -7. [PubMed: 16798215]
5. DeCamp MM Jr. Lipson D, Krasna M, Minai OA, McKenna RJ Jr. Thomashow BM. The evaluation and preparation of the patient for lung volume reduction surgery. *Proceedings of the American Thoracic Society*. May 1; 2008 5(4):427–31. [PubMed: 18453350]
- 6**. DeCamp MM Jr. McKenna RJ Jr. Deschamps CC, Krasna MJ. Lung volume reduction surgery: technique, operative mortality, and morbidity. *Proceedings of the American Thoracic Society*. May 1; 2008 5(4):442–6. [PubMed: 18453353] [Outstanding evidence and reviews on LVRS worth reading for more in depth details of every phase of LVRS care.]
- 7**. Brister NW, Barnette RE, Kim V, Keresztury M. Anesthetic considerations in candidates for lung volume reduction surgery. *Proceedings of the American Thoracic Society*. May 1; 2008 5(4): 432–7. [PubMed: 18453351] [Outstanding evidence and reviews on LVRS worth reading for more in depth details of every phase of LVRS care.]
- 8**. Sharafkhaneh A, Falk JA, Minai OA, Lipson DA. Overview of the perioperative management of lung volume reduction surgery patients. *Proceedings of the American Thoracic Society*. May 1; 2008 5(4):438–41. [PubMed: 18453352] [Outstanding evidence and reviews on LVRS worth reading for more in depth details of every phase of LVRS care.]
- 9**. Naunheim KS, Wood DE, Mohsenifar Z, Sternberg AL, Criner GJ, DeCamp MM, et al. Long-term follow-up of patients receiving lung-volume-reduction surgery versus medical therapy for severe emphysema by the National Emphysema Treatment Trial Research Group. *Ann Thorac Surg*. Aug; 2006 82(2):431–43. [PubMed: 16888872] [Outstanding evidence and reviews on LVRS worth reading for more in depth details of every phase of LVRS care.]
- 10**. Patients at high risk of death after lung-volume-reduction surgery. *The New England journal of medicine*. Oct 11; 2001 345(15):1075–83. [PubMed: 11596586] [Outstanding evidence and reviews on LVRS worth reading for more in depth details of every phase of LVRS care.]
11. Naunheim KS, Wood DE, Krasna MJ, DeCamp MM Jr. Ginsburg ME, McKenna RJ Jr. et al. Predictors of operative mortality and cardiopulmonary morbidity in the National Emphysema Treatment Trial. *J Thorac Cardiovasc Surg*. Jan; 2006 131(1):43–53. [PubMed: 16399293]
12. Nici L, Donner C, Wouters E, Zuwallack R, Ambrosino N, Bourbeau J, et al. American Thoracic Society/European Respiratory Society statement on pulmonary rehabilitation. *American journal of respiratory and critical care medicine*. Jun 15; 2006 173(12):1390–413. [PubMed: 16760357]
13. Ries AL, Bauldoff GS, Carlin BW, Casaburi R, Emery CF, Mahler DA, et al. Pulmonary Rehabilitation: Joint ACCP/AACVPR Evidence-Based Clinical Practice Guidelines. *Chest*. May; 2007 131(5 Suppl):4S–42S. [PubMed: 17494825]
14. Benzo R, Chang CC, Farrell MH, Kaplan R, Ries A, Martinez FJ, et al. Physical Activity, Health Status and Risk of Hospitalization in Patients with Severe Chronic Obstructive Pulmonary Disease. *Respiration*. Mar 16.
15. Bandura A. Health promotion by social cognitive means. *Health Educ Behav*. Apr; 2004 31(2): 143–64. [PubMed: 15090118]
16. Bernardi L, Gabutti A, Porta C, Spicuzza L. Slow breathing reduces chemoreflex response to hypoxia and hypercapnia, and increases baroreflex sensitivity. *Journal of hypertension*. Dec; 2001 19(12):2221–9. [PubMed: 11725167]
17. Bernardi L, Porta C, Spicuzza L, Bellwon J, Spadacini G, Frey AW, et al. Slow breathing increases arterial baroreflex sensitivity in patients with chronic heart failure. *Circulation*. Jan 15; 2002 105(2):143–5. [PubMed: 11790690]
18. Raupach T, Bahr F, Herrmann P, Luethje L, Heusser K, Hasenfuss G, et al. Slow breathing reduces sympathoexcitation in COPD. *Eur Respir J*. Aug; 2008 32(2):387–92. [PubMed: 18385175]

19. Hulzebos EH, Helders PJ, Favie NJ, De Bie RA, Brutel de la Riviere A, Van Meeteren NL. Preoperative intensive inspiratory muscle training to prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery: a randomized clinical trial. *Jama*. Oct 18; 2006 296(15):1851–7. [PubMed: 17047215]
20. Hurst JR, Vestbo J, Anzueto A, Locantore N, Mullerova H, Tal-Singer R, et al. Susceptibility to exacerbation in chronic obstructive pulmonary disease. *The New England journal of medicine*. Sep 16; 363(12):1128–38. [PubMed: 20843247]
21. Bourbeau J, Julien M, Maltais F, Rouleau M, Beaupre A, Begin R, et al. Reduction of hospital utilization in patients with chronic obstructive pulmonary disease: a disease-specific self-management intervention. *Archives of internal medicine*. Mar 10; 2003 163(5):585–91. [PubMed: 12622605]
22. Rice KL, Dewan N, Bloomfield HE, Grill J, Schult TM, Nelson DB, et al. Disease Management Program for Chronic Obstructive Pulmonary Disease: A Randomized Controlled Trial. *American journal of respiratory and critical care medicine*. Jan 21.
23. Hillier J, Gillbe C. Anaesthesia for lung volume reduction surgery. *Anaesthesia*. Dec; 2003 58(12): 1210–9. [PubMed: 14705686]
24. Hartigan PM, Pedoto A. Anesthetic considerations for lung volume reduction surgery and lung transplantation. *Thoracic surgery clinics*. Feb; 2005 15(1):143–57. [PubMed: 15707352]
25. Singhal S, Ferraris VA, Bridges CR, Clough ER, Mitchell JD, Fernando HC, et al. Management of alveolar air leaks after pulmonary resection. *Ann Thorac Surg*. Apr; 89(4):1327–35. [PubMed: 20338378]

Summary of meaningful aspects of LVRS care

Preoperative care roots in proper patient selection and specialized pulmonary rehabilitation.

Hypotension, Hypercapnia and Hypoxemia are the most frequent problems during the procedure.

Post operative care in LVRS aims to four specific actions: early extubation, the prevention/treatment of air leaks and respiratory failure and early ambulation.