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Lung volume reduction surgery – a comparison of the long term outcome of unilateral vs. bilateral approaches ☆

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Abstract

Objective: Bilateral lung volume reduction surgery (LVRS) is thought to be preferable to unilateral surgery due to greater initial benefit but the subsequent rate of decline may also be greater. We compared the long term physiological and health status outcome of LVRS performed on one or simultaneously on both lungs. **Methods**: Prospective data were collected on a consecutive series of 65 patients undergoing LVRS who were all suitable for bilateral surgery. Twenty-six patients: age 59 (8) years underwent bilateral LVRS by video-assisted thoracoscopy (VAT) or sternotomy and 39 patients: age 60 (6) years underwent unilateral VAT. The perioperative effects of LVRS on spirometry were prospectively recorded at 3, 6, 12 and 24 months. **Results**: The unilateral group had similar preoperative lung volumes to the bilateral patients: forced expiratory volume in 1 s (FEV_1) 26 vs. 30% predicted, RV 275 vs. 246% predicted and total lung capacity (TLC) 148 vs. 142% predicted. Unilateral LVRS was associated with significantly lower weight of lung resected: 80 (31) vs. 118 (46) g; hospital stay: 16 (10) days vs. 28 (22) days. Thirty-day mortality was 3% in the unilateral and 8% in the bilateral group ($P = 0.34$). Postoperative ventilation occurred in 5% in the unilateral and in 42% in the bilateral group ($P = 0.0002$). The decline of FEV_1 during the first postoperative year was significant in the bilateral group (−313 ml/y, $P = 0.04$) but not significant in the unilateral group (−50 ml/y, $P = 0.18$). SF 36 scores in all eight domains were similar in both groups preoperatively and at any postoperative interval. **Conclusion**: We have found no benefit from bilateral simultaneous LVRS and prefer unilateral LVRS because of the lower morbidity, resulting in earlier discharge, and slower decline in physiological benefit.

Keywords: Lung volume reduction surgery; Video-assisted thoracoscopy; Emphysema

1. Introduction

Lung volume reduction surgery (LVRS) was first described in 1958 by Otto Brantigan [1]. He described an approach via lateral thoracotomy in which the peripheral areas of the lung were excised. This technique was not widely accepted due to the associated high mortality, although some surgeons persisted with the operation with favourable outcome [2,3].

Cooper et al. [4] re-introduced the concept of LVRS via median sternotomy incorporating simultaneous bilateral surgery. The introduction of video-assisted thoracoscopic (VAT) techniques prompted a unilateral approach [5,6] with subsequent reports on staged bilateral VAT surgery (VATS) procedures [7]

The first major comparison between unilateral and bilateral approaches suggested improved early functional benefits and survival following bilateral LVRS [8]. This approach has been subsequently adopted as the standard. Doubts still remain, however, regarding the validity of this argument, since none of the comparisons of approach were randomised, there is an accepted variability in results from LVRS (due to factors other than the surgical approach) and the comparative long term effects are unknown. It has been suggested that the decline in physiological benefit of LVRS may be accelerated by an initial bilateral approach [9].

2. Patients and methods

Over a 5-year period, we have assessed 218 patients for LVRS by a multi-disciplinary selection panel comprising: a respiratory physician, a physiotherapist, two radiologists and two surgeons. All patients underwent physical examination, basic spirometry, plethysmography, arterial blood

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gas analysis, chest radiography, computed tomography and radionuclide ventilation/perfusion scintigraphy.

2.1. Selection criteria

Patients had to have significant symptomatic dysfunction judged by the modified Medical Research Council (MRC) dyspnoea scale as grade 3–5. Spirometric inclusion criteria consisted of a forced expiratory volume in 1 s (FEV_1) of 15–40% of predicted; residual volume (RV) in excess of 140% of predicted; total lung capacity (TLC) greater than 120% of predicted and a RV:TLC ratio over 60%. Anatomical criteria included the presence of heterogeneous emphysema with target areas of severe emphysema on computed tomographical (CT) scan. Physiological heterogeneity was assessed on radionuclide scintigraphy. This was quantitated by calculating the so-called *Q* score, as determined by the ratio of perfusion in the target zone to the total lung perfusion [10]. Patients with target areas in either upper or lower lobes were included.

Exclusion criteria included single large bullae, hypercapnia (pCO_2 greater than 7 kPa or 53 mmHg), greatly reduced diffusion capacity (carbon monoxide transfer coefficient (KCO) less than 25% of predicted).

All patients underwent preoperative pulmonary rehabilitation. Exercise tolerance was assessed using the shuttle walk test (SWT). This is an externally paced field walking test using a 10 m course. Although there is a significant relation between the distance walked in the SWT and the 6 min walking test, the SWT is thought to be more reproducible and to cause a more graded cardiovascular response than the self paced 6 min walking test [11]. Patients who could not complete a distance of 150 m in a SWT did not proceed to operation. Rehabilitation was carried out as a 7-week out-patient or 2-week in-patient programme.

Before surgery but after rehabilitation patients completed short-form 36-item (SF 36) and Euroquol questionnaires.

2.2. Surgical approach

At the start of the series, all operations were performed bilaterally via median sternotomy. Subsequently one of the surgeons adopted a policy of bilateral VATS and latterly a policy of staged unilateral VATS, operating on the least perfused lung first, with the timing of the second operation determined by the patient on the basis of symptomatic deterioration. All operations entailed stapled resection of functionless areas of lung using bovine pericardial buttresses (Peri Strips, Bio-Vascular, Minnesota).

2.3. Postoperative follow-up

Patients were reviewed as out-patients at 3, 6, 12 and 24 months postLVRS. At each visit, patients underwent detailed spirometry and plethysmography. They also completed SF 36 and Euroquol health status questionnaires.

2.4. Statistical analysis

Data were analysed using SPSS Version 9.0 statistical software. The relationships between preoperative and postoperative variables were assessed using paired and unpaired Student's *t*-test. The Wilcoxon rank-sum test was used to compare inter-group differences in the change in pulmonary function. The Fisher's exact test was used for discrete variables. All *P*-values were reported without corrections for multiple comparisons, a *P*-value less than 0.05 was considered to indicate a statistically significant difference.

3. Results

Of 218 patients evaluated for surgery, 65 (30%) patients were selected for LVRS. Bilateral LVRS was performed in 26 patients (by median sternotomy in 18 and by VATS in eight) and unilateral VAT LVRS in 39 patients. Of the 65 patients, data were available on 58 patients at 3 months (six had died before their 3-month follow-up, no data was available in one patient). At 6 months, data were available on 57 patients (one further patient had died). At 1 year, data were available on 49 patients (two further patients were lost to follow-up and six have not reached their 1 year follow-up). At 2 years, data was available for 32 patients only.

3.1. Preoperative characteristics (Tables 1 and 2)

There were no significant differences in the age/gender distribution, dyspnoea scores or SWTs between the two groups. There was also no significant inter-group difference in the degree of airways obstruction, hyperinflation, diffusion capacity or gas exchange.

3.2. Perioperative course (Table 3)

A significantly greater amount of lung tissue was resected in the bilateral operations. The 30-day mortality was 4.6% in this series, two occurred after bilateral LVRS due to respiratory failure and one after unilateral surgery, which was attributed to delayed haemorrhage, following removal of a chest tube. There was also a significantly longer Intensive Therapy Unit (ITU) and in-hospital stay after bilateral surgery.

Table 1
Preoperative characteristics

	Mean (SD)	
	Unilateral	Bilateral
Age (yr)	60 (6)	59 (8)
Gender (M/F)	26/13	16/10
MRC dyspnoea	3.9 (0.6)	4.2 (0.4)
SWT (m)	234 (107)	219 (88)

Table 2
Preoperative respiratory function

	Mean (SD)	
	Unilateral	Bilateral
PaO_2 (kPa)	9.3 (1.1)	8.9 (1.2)
PaO_2 (mmHg)	70 (8)	67 (9)
$PaCO_2$ (kPa)	5.2 (0.6)	5.0 (0.7)
$PaCO_2$ (mmHg)	39 (5)	38 (5)
FEV_1 (l)	0.75 (0.3)	0.85 (0.3)
FEV_1 (% predicted)	26 (9)	30 (9)
RV (% predicted)	275 (58)	246 (60)
TLC (%predicted)	148 (18)	142 (21)
RV:TLC (%)	67 (9)	63 (9)
DLCO (% predicted)	44 (13)	43 (11)
Raw	10.3 (4.7)	12.5 (3.4)

3.3. Postoperative change in pulmonary function (Table 4, Fig. 1)

Three and 6 months after LVRS, there was a significant improvement in FEV_1 in each group, the changes were similar for unilateral and bilateral surgery. At 12 months, the changes in the bilateral group were no longer significant, while the changes in the unilateral group were still significantly improved.

The decline of FEV_1 during the first postoperative year was significant in the bilateral group (-313 ml/y, $P = 0.04$) but not significant in the unilateral group (-50 ml/y, $P = 0.18$).

3.4. Postoperative change in health status (Fig. 2)

In both groups there was an improvement in SF 36 scores, which remained statistically significant for up to 12 months after LVRS in the health domains concerned with physical functioning and social functioning. The best improvement was seen at 6 months. At 24 months, the unilateral group showed only two domains in which the score remained higher than preoperative values while in the bilateral group seven out of eight domains still had a higher score than preoperatively. However, there was no significant difference in the scores between the two groups at any time.

3.5. Survival

The actuarial survival for the entire group at 6, 12 and 24 months was 89, 89 and 87%, respectively. There was no significant difference in survival between the two groups at 24 months after LVRS ($P = 0.58$).

Table 3
Perioperative course

	Mean (SD)		*P*-value
	Unilateral	Bilateral	
Lung resected (g)	80 (41)	118 (46)	0.0003
ITU stay (days)	2 (13)	7 (9)	0.04
Postoperative stay (days)	16 (10)	28 (22)	0.004
Postoperative ventilation	2/39 (5%)	11/26 (42%)	0.0002
30 day mortality	1/37 (3%)	2/26 (8%)	0.34

Table 4
Postoperative change in FEV_1 (% predicted)

	Mean (SD)	
	Unilateral	Bilateral
Preoperation	26 (9)	30 (9)
3 months post LVRS	34 (12)	38 (14)
6 months post LVRS	31 (13)	38 (15)
1 year post LVRS	31(113)	35 (13)
2 year post LVRS	34 (15)	31 (13)
Decline during first postoperative year (ml/yr)	− 50	− 313

4. Discussion

McKenna et al. [8] analysed the early outcome of 166 patients who were operated by either bilateral or unilateral

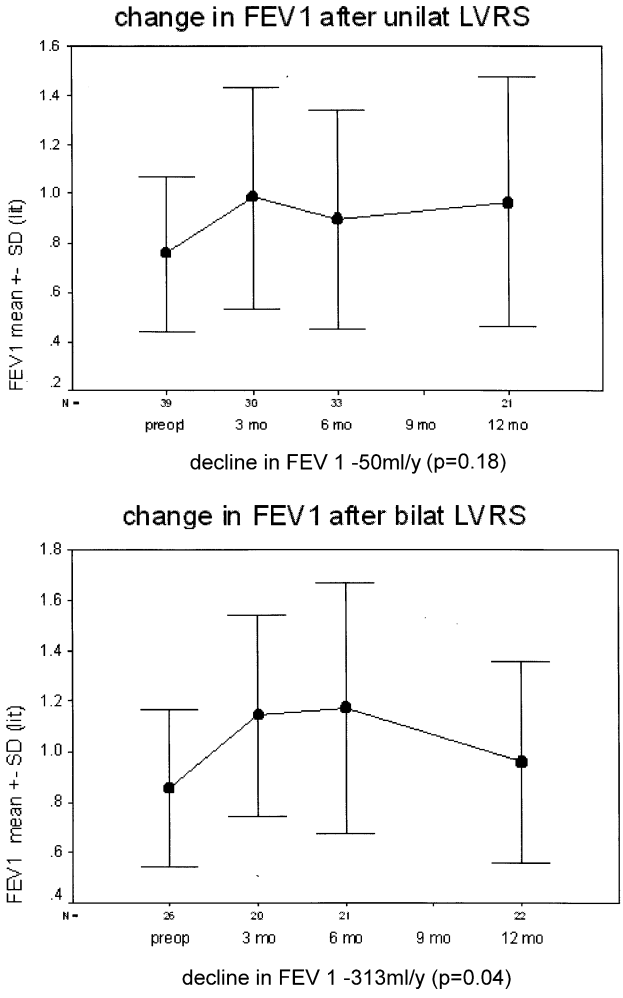

Fig. 1. FEV_1 decline during first postoperative year.

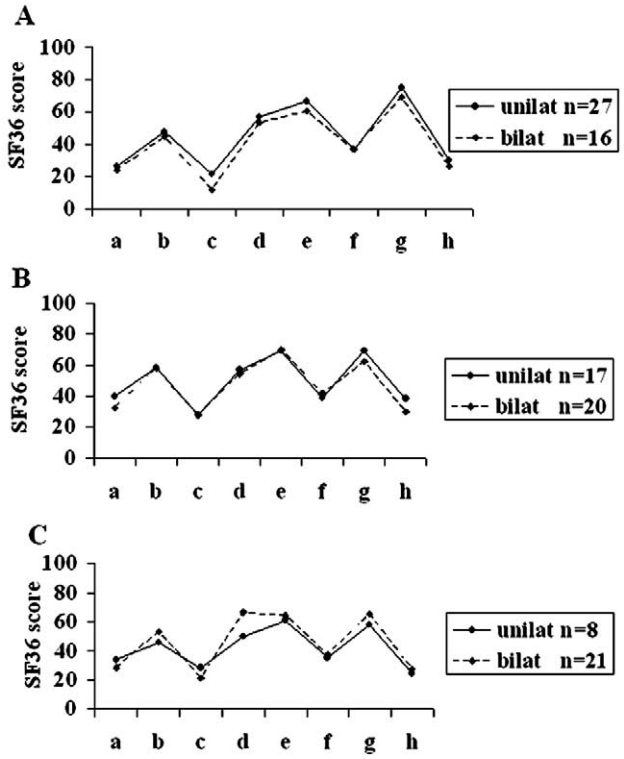

Fig. 2. Health status: (A) preoperatively; (B) at 1 year; (C) at 2 years (a: physical functioning; b: social functioning; c: role limitation due to physical functioning; d: role limitation due to emotional functioning; e: mental health; f: energy/vitality; g: pain; h: general health perception).

VATS in a non-randomised comparison. There was no difference in the operative morbidity or mortality and the postoperative stay was comparable. However, there was found to be a higher late mortality in patients who had undergone unilateral surgery and these patients also had a smaller improvement in dyspnoea, oxygen requirement and steroid usage than those undergoing bilateral LVRS. The authors therefore advocated a bilateral approach wherever possible [8,12]. This group subsequently reported their longer term functional results with a variety of surgical approaches [9]. In a group of 376 patients, Brenner et al. found that there was a greater short-term physiological benefit from bilateral LVRS but noted a more rapid rate of FEV_1 decline in these patients. There was also found to be an association between the magnitude of short-term improvement and the rate of deterioration in FEV_1. The mechanism for this finding may be that the increase in lung elastic recoil effected by LVRS may increase the normal daily stress on alveoli during tidal breathing and thereby accelerate the age-related increase in alveolar size in the remaining lung [13].

Whilst bilateral LVRS appears to yield greater improvements in spirometric variables, there has not been a similar a benefit found in other outcome measures. Similar improvements have been noted in relief of dyspnoea and in exercise tolerance from each approach [14,15]. Mahler et al. [16] evaluated the use of SF 36 questionnaires in patients with chronic obstructive pulmonary disease (COPD) and found the severity of dyspnoea but not respiratory function to be a significant predictor of health status outcome. Leyenson et al. [17] also found that the improvements in health status related to LVRS did not correlate with changes in pulmonary function but were more closely related to reduced requirement for medical treatment (i.e. reduced steroid use and oxygen requirement). Simple evaluation of spirometric variables may not therefore be the most meaningful way of comparing the different LVRS approaches.

Our findings of increased ventilation, ITU and in-hospital stay from bilateral surgery reflect those of other series [18]. Our policy now is to perform LVRS on the contra-lateral side if and when the patient wishes to proceed and provided our selection criteria are still fulfilled. So far three patients have had LVRS on the opposite side after 1, 2 and 4 years after their first operation (data not shown). It has been argued that although unilateral LVRS results in shorter hospitalisation, in a staged bilateral procedure, the total of the two stays would be longer than the stay for bilateral LVRS [5]. However, shorter ventilation and ITU stay would still favour a staged procedure. Hence, there will be additional health cost due to a total longer in-hospital stay.

This study has the obvious limitation that it was not a prospective, randomised study. Nevertheless there were no significant differences between the unilateral and bilateral groups even in the distribution of emphysema. Some of the reported studies on unilateral LVRS were performed on patients with only unilateral target areas in several patients [14]. However, all patients in our group had bilateral heterogeneous disease. This was determined in a quantitative manner using quantitative perfusion scintigraphy. The *Q* score was not significantly different in the two groups.

Part of the explanation for the difference in morbidity may be attributed to the fact that the early procedures in the series were bilateral. Increasing perioperative experience may partly explain better results later in the series. The study also compares the relative morbidity of sternotomy and VATS since a high proportion of the bilateral operations were performed by sternotomy. Others have found longer ITU and hospital stay in median sternotomies compared to VATS [19,20]. However, a comparable portion of patients with bilateral VATS compared to median sternotomy developed respiratory failure requiring ventilation (four out of eight VATS patients vs. seven out of 18 median sternotomy patients). Both operating surgeons performed open surgery.

No previous study has reported a detailed comparative analysis of postoperative health status changes using SF 36. We have demonstrated non-significant difference between the two approaches. We preferred to use the SF 36 questionnaire rather than a disease-specific instrument so that we could measure the impact of LVRS on various different aspects of health status. However, generic instruments are less sensitive to changes than disease-specific

questionnaire and small differences between the two groups may not be detected.

In conclusion, during a 2-year follow-up, we found that unilateral LVRS resulted in comparable results as bilateral LVRS, with regard to lung function and health status but resulted in faster recovery with less morbidity. We therefore favour a two-staged procedure. Our future work will include a prospective randomised comparison of one-stage bilateral VAT LVRS vs. two-stage unilateral VAT LVRS. We continue to observe the longitudinal benefit in those patients currently engaged in a staged-unilateral programme.

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Appendix A. Conference discussion

Dr H. Toomes *(Stuttgart, Germany)*: I didn't get the figure, how many of these unilaterals did you operate upon later on as a second volume reduction on the other side?

Mr Waller: At present we have operated on three of that population at a variable interval, the longest being three and a half years after the first operation. The decision to reoperate on the other side is based in conjunction with the patient when they feel their symptoms have deteriorated significantly to wish to have the operation and providing they fulfill the standard criteria of the operation.

Dr Toomes: Yes. I thought about the costs, because if you calculate the costs, they will be the same, only one year later.

Mr Waller: Exactly, but the interval is certainly more than one year.

Mr R. Qureshi: *(Solihull, UK)*: Mr. Waller, did you measure the diaphragmatic function in any of these patients?

Mr Waller: No, we don't measure diaphragmatic function by pressure. We measure lung volumes postoperatively, but not specifically diaphragmatic function. Although we do note that after unilateral surgery, the contralateral diaphragm has a restoration of its normal contour. Despite operating on the right side, for example, the left hemidiaphragm will show a restoration in its contour.

Mr Qureshi: Were there any patients you referred for lung transplantation among your series?

Mr Waller: No, we have referred none of these patients for lung volume reduction surgery, although during this time we operated on 30% of our referrals, and I think we have offered two patients who we have turned down for surgery for lung transplantation.